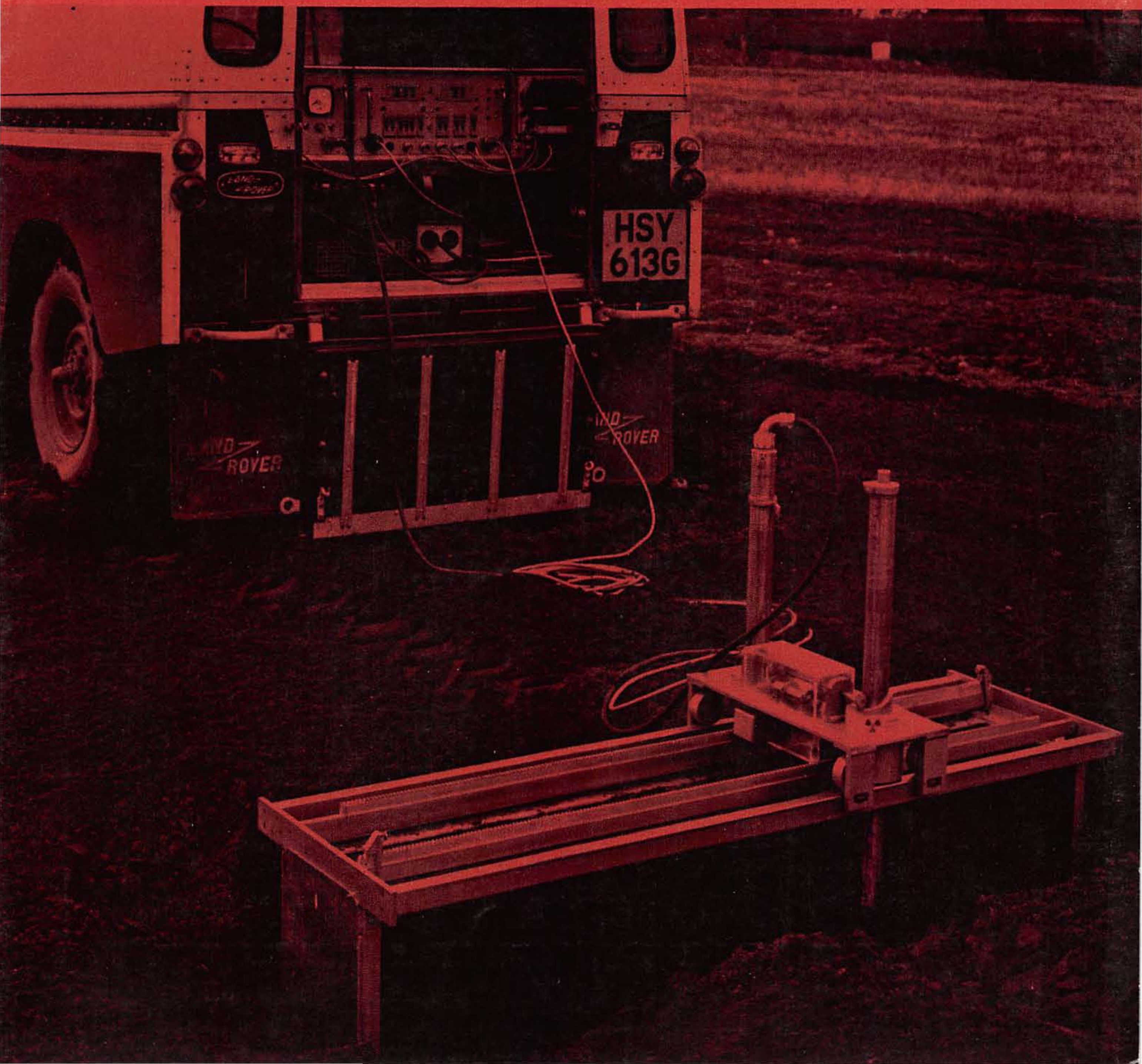
I AGR E

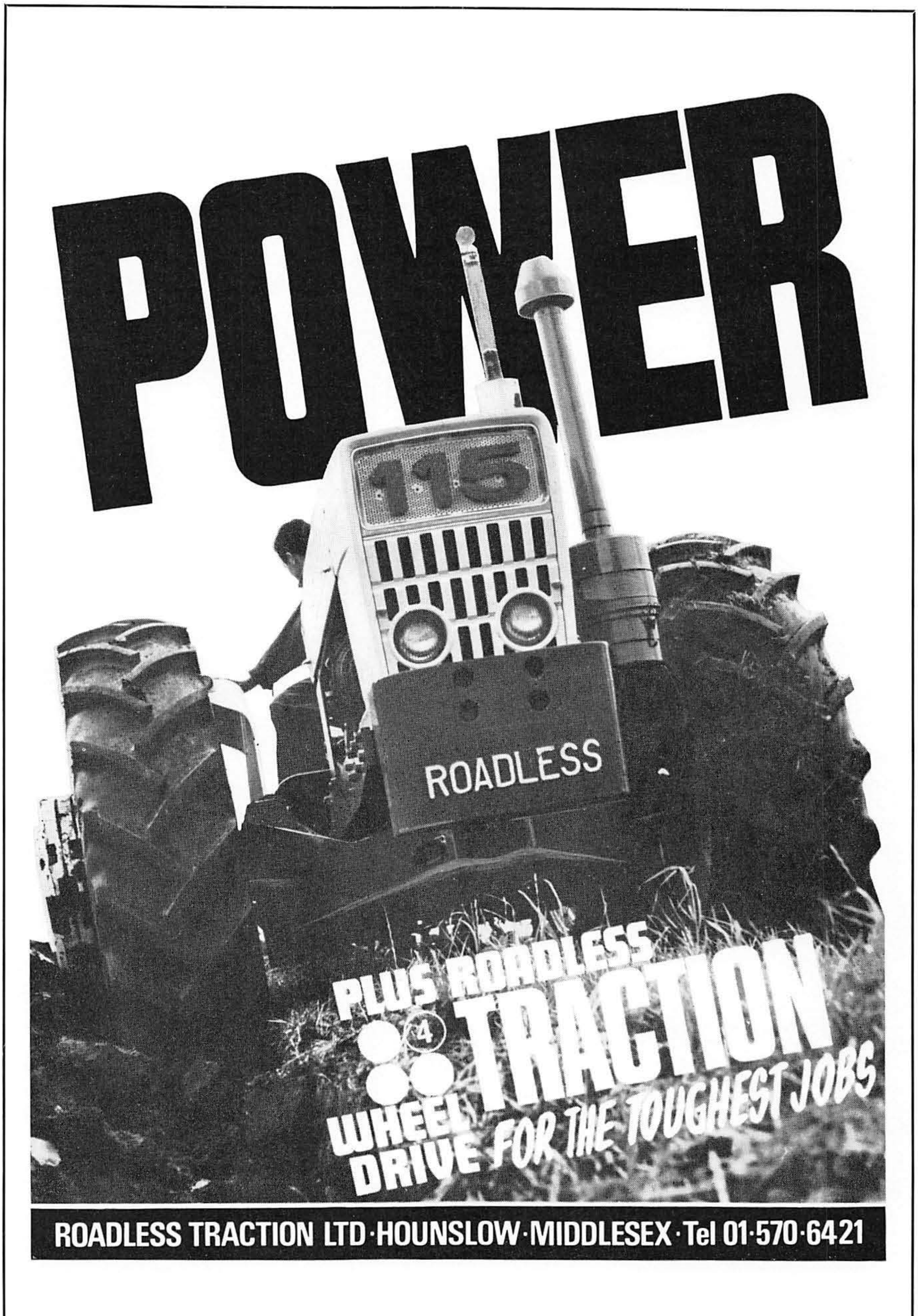
Volume 25

Number 3

Autumn 1970

CULTIVATIONS
Influences on Soil Properties
Effects of Traffic
and Implements
on Soil Compaction




POWER
115
ROADLESS
PLUS ROADLESS
4
WHEEL
DRIVE
TRACTION
FOR THE TOUGHEST JOBS
ROADLESS TRACTION LTD·HOUNSLOW·MIDDLESEX·Tel 01·570·6421

JOURNAL

and Proceedings of

THE INSTITUTION of AGRICULTURAL ENGINEERS

AUTUMN 1970 **Volume 25** **Number 3**

The Front Cover illustration is taken from Figure 7 of the paper by B. D. Soane

Published Quarterly by the Institution of Agricultural Engineers, Penn Place, Rickmansworth Herts., WD3 1RE. Telephone: Rickmansworth 76328

Price: 15s. (75 p) per copy. Annual subscription: £3 0 0 (post free in U.K.)

The views and opinions expressed in Papers and individual contributions are not necessarily those of the Institution.

GUEST EDITORIAL

It was originally intended that Ben Burgess should be a farmer; indeed he still farms the 500 acres of heavy land where he was born but, in 1931, the engineering in his blood proved too strong and he started the business now known as Ben Burgess & Company, which is the parent company of a small group of subsidiaries in associated trades.

He was an early member of the Institution and helped to form the East Anglian Branch, of which he was Chairman in 1951–52. He is currently a member of the Institution's Council and serves on the Education and Papers Committees. He is a past President of A.M. & T.D.A. and is currently President Elect of the Royal Norfolk Agricultural Association.
Because he holds stirring opinions on the subject of cultivations—the theme running through this and the next issue of I AGR E—Ben Burgess was invited to contribute this Editorial.

WORSHIPPING THE SACRED CLOD

by BEN BURGESS, DIP AGRIC, FI AGR E

Perhaps it is because there are as many variables in the physical condition of soils as there are methods of applying the art of cultivation that any written paper on the subject is liable to annoy some readers and any conference is in danger of frustrating some of the audience. And a jolly good thing too! Because, when this happens, it is certain that a few more people may be stimulated to original thought on the subject.

Most speakers at the Institution's 1970 Annual Conference on the subject certainly stimulated me, because they appeared to have approached the subject of cultivation with the conventional Mrs Beeton philosophy of 'first make your clod'. Indeed, I had the feeling that, at any moment, the sacred clod would materialise above the chairman's head and that we should then be called upon to do obeisance to it. I agree that makers and vendors of cultivating machinery should certainly worship the clod. It is their *raison d'etre* and much of their livelihood. I know there are many farmers who quite deliberately make clods, in the genuine belief that there is some virtue in this soil condition. I am absolutely certain that the generality of farmers in Britain spend millions of pounds each year in first making clods and then breaking them down again, QUITE UNNECESSARILY.

In general, clods are made twice a year; once in the late summer and early autumn (by ploughs and deep cultivators) in preparation for autumn sown cereals and, again, in the springtime (by various tined cultivators).

The autumn clods in particular are a delight to the farmer on heavy land. When land is dry and compacted, ploughs and heavy cultivators can only operate at a uniform depth if they are allowed to penetrate quite deeply. The harder the work and the better the clods, the greater the cost of breaking them down again. And yet equipment now exists which enables the farmer to break up the first few inches of the stubble or layer without making clods, which can be subsequently followed by shallower and therefore less expensive ploughing. In this way, by balancing the depth of surface penetration against the depth of subsequent ploughing, the farmer can adjust the soil texture he requires for his autumn seedbed without any further cultivation. This technique also offers a bonus of fine soil particles mixed with decomposing trash, which is ploughed in to a depth at which it is of immediate benefit to cereal root development.

There is no need for me to re-state the objects of winter ploughing. They are well known in theory and have not changed since the invention of the mouldboard. Let us, however, examine what happens in practice and study the accepted method of clod making in the springtime. The heavier the soil, the stronger the furrow slice and the less able it is to bend with the twist of the plough breast without fracture. In general terms, the frequency of the fractures depends on the length of the breast and the speed of ploughing. It is not uncommon to see heavy land ploughing where the fractures have occurred every 3-4 ft. Immediately after the point of fracture, the new section of furrow is thrown on top of the furrow slice preceding it. Walking behind a 3-furrow plough when this is being done is an exhilarating experience but the effect is not so beneficial to the farmer. At the point where the furrow slice is thrown, a gap appears, through which the furrow bottom is clearly visible. The effect of this when ploughing a 12 in. × 8 in. furrow is a contour variation of up to 16 in. between 12 in. centres at every point of fracture. These groups of high points and hollows appear at a frequency of nearly one pair per square yard. If surface stubble cultivation to a uniform depth has been done, the furrow slice is not so strong and therefore it will not fracture so frequently or throw so far.

Winter weathering certainly rounds off the peaks and partly fills up the holes, but, under the best weathering conditions, contours usually still vary as much as 10 in. when spring cultivations begin. In 1964 Hawkins wrote 'The idea that rough winter ploughing will weather down into a good spring seedbed is wrong'. He could hardly have foreseen how very rough heavy land ploughing was going to be in the 70's. He continues 'Cultivation then removes most of the weathered soil from the peaks and puts it into the hollows, exposing a good deal of the unweathered soil'. He might have saved his typewriter ribbon! To obtain a level seedbed from such ploughing usually requires either an excessive number of passes of light conventional cultivation implements (which make large numbers of small clods) or one pass of a heavy cultivator (which produces a smaller number of much better ones). The farmer can then chop, erode or pulverise them to break them down again, with all the tractor passes this entails. Either way, the benefits of winter weathering are largely lost and the seed is liable to be sown in an artificial tilth consisting of much larger soil granules than were on the surface when spring cultivations began. But perhaps more damaging than the loss of the friable tilth from the surface is that it has changed place with some of the unweathered soil from below, where it is soon compacted into a putty-like layer by the repeated passage of tractor wheels. At the same time, much of the air has been squeezed out of the whole plough layer and a good deal of the moisture has been evaporated.

Avoidance of these damaging side effects and a considerable reduction of the cost of cultivations can begin in the Autumn by attention to the four factors governing the operation of ploughing and arriving at a balance to suit each individual soil condition, between width and depth of furrow and between length of breast and operational speed. And in the springtime farmers should consider the advantages of alternatives to the now traditional curved or 'C' type cultivator tine in favour of the vertical tine, either rigid, mechanically vibrated or spring oscillating. □

INSTITUTION NOTES

The Institution and CEI

On 3 July, the Board of the Council of Engineering Institutions (CEI) unanimously passed Special Resolutions proposing changes in its Charter and By-Laws to be forwarded to the Privy Council for approval to establish and maintain a composite Register for the three sections of the engineering community.

The three sections of the Register will deal respectively with the Chartered Engineer, the Technician Engineer and the Technician. The first section of the Register will cover Chartered Engineers for whom the designatory initials will continue to be *C Eng*. It is now thought likely that the designatory letters for those individuals nominated by their Institutions to the *new* sections of the CEI Register will be *T Eng* (*CEI*) for Technician Engineers and *Tech* (*CEI*) for Technicians. As previously announced, CEI intends setting up the Technician Engineer section without delay and also announces its intention to introduce the Technician section as soon as practicable thereafter.

Whilst the Privy Council have already intimated their agreement in principle to the establishment by CEI of such a Register, and to the granting of titles and designatory letters, it will take a little time for the formal submissions to be approved and for consultations in detail to take place between CEI and those Institutions and Societies that will be involved. This Institution is among the bodies already actively assisting CEI in setting up the organisation for the new sections of its Register. The Register as a whole is likely to be administered by a new Engineers Registration Board, in which the Institution will be represented. This should establish the Institution's exclusive right to sponsor suitably qualified agricultural engineers via the Member (*MI Agr E*) grade for the designation *T Eng* (*CEI*). At a later stage individually qualified Associates (*AI Agr E*) should be able to claim similar registration facilities for the designation *Tech* (*CEI*) but this latter section of the Register is still only at the outline stage.

So far, there is little sign that affiliation of the Institution to CEI, which was the subject of a Special Resolution at the Institution's AGM in May, must first take place before registration facilities can be made available to agricultural engineers. Instead, it now seems possible that the Institution must show itself to be a bona fide qualifying body actually serving on the aforementioned Engineers Registration Board, before affiliation will be considered. This must remain somewhat in the realm of speculation until CEI spells out details of its proposals for affiliating suitable non-chartered Institutions.

The problem of finding a route through for Fellows of the Institution to register for the title *C Eng* without first having to join one of the fourteen chartered engineering Institutions, still defies early solution. A hopeful sign is that CEI itself acknowledges the dilemma. A possibility is that the new Engineers Registration Board, comprising chartered and non-chartered Institutions alike, might provide a useful 'Speakers' Corner' wherein the engineering community can address itself to a range of problems and set its world to rights.

Seen as a whole, the slowly emerging pattern for a comprehensive registration system for the engineering community looks promising and deserves to succeed. Some recent words of the CEI Chairman, Sir Eric Mensforth, CBE, are encouraging. In a statement immediately after the CEI Board meeting in July, he said 'The establishment of this Register marks a very important further phase in the development of CEI, in serving all qualified members of the engineering community. It provides worthy personal objectives in each section and a ladder of progression between them'.

New Part III Regulations

As from 1 January 1971, *all* candidates for election or transfer to the grade of *Fellow* will have to satisfy the Institution Council as to their professional training, experience and responsibility in a Part III Review to be assessed at a degree level standard of accomplishment. This will normally be required *in addition to* a Part IIB academic qualification but any candidate aged 40 years or above who does not possess a Part IIB qualification may at the discretion of the Council in each individual case secure exemption therefrom if he displays unusually outstanding merit in the Part III Review.

Candidates for admission or transfer to the corporate grade of *Member* from January 1971 will not normally be required to undergo the new Part III Review provided they hold a Part IIA (or Part IIB) qualification. However, any candidate aged 30 years or over who applies for entry to the grade of Member and who does not hold a Part IIA (or Part IIB) qualification might at the discretion of the Council in each individual case be able to secure exemption therefrom by successfully undergoing a Part III Review to be assessed at a diploma level standard of accomplishment.

The following table indicates the levels of academic attainment that will apply to the grades of corporate and Graduate membership from 1 January 1971.

Technical Qualifications required in addition to Part I from January 1971 to December 1973 inclusive

Age	Graduate	Member	Fellow
Under 30	Part II (A or B)	Part IIA	(not applicable)
30-40	Part II (A or B)	Part IIA or Part III	Part IIB and Part III
Over 40	(not normally applicable)	Part IIA or Part III	Part IIB and/ or Part III

A candidate who has qualified in Part IIB will be deemed exempt from Part IIA.

If as a result of examination of his application for admission or transfer a candidate is judged eligible to apply for Fellowship (or where appropriate in a particular case, for Membership) he will be declared eligible by the Council to undergo a Part III Review to be conducted at a degree level or diploma level standard of assessment, as the case may be.

The Part III Review will be in two parts. First, the candidate must present two copies of a report covering his background, career accomplishments and responsibilities.

Guidance on its preparation will be supplied by the Secretary to the candidate at the time he is asked to present the report. Secondly, the candidate may then be required to attend an interview, which will normally be held in London. In cases of extreme difficulty or if the candidate resides overseas, arrangements may be made for the candidate to be seen by an interviewer nominated by the Institution from members resident in, or visiting the country or area concerned. The candidate may also be examined by means of a thesis or other academic test, either in addition to or instead of an interview.

Candidates will be notified by the Institution if they are required to be interviewed and/or to undergo examination by a thesis or other academic test.

The fee for a Part III Review will be £5; this sum must accompany the candidate's report and will be non-refundable. The new Part III Review will cancel and replace the current Part III procedure from 1 January 1971, and intending candidates for corporate membership whose applications are received by the Institution during December 1970 will automatically fall within the purview of the new Regulations.

Clearer Definition of Fellowship Requirements

The Institution requires a Fellow to be qualified at a level not lower than that prescribed for chartered engineers by the proposed Engineers Registration Board shortly expected to be set up under the chartered mandate of CEI. Fellowship must therefore continue to demand a qualification at least equivalent to a first degree from a British university.

This is reflected in the Institution's Part IIB level of attainment. The Council may, at its discretion, declare a candidate for Fellow aged over 40 years exempt from Part IIB if he displays exceptional merit in the Part III Review described earlier in these Notes.

From 1 January 1971, a primary purpose of the Part III Review, which every candidate for the grade of Fellow must undergo, will be to prove that the applicant has had at least eight years experience which, inclusive of full time training, is consistent with degree-level ability in the realms of engineering, agriculture or an applied branch of pure science.

For at least five years (any part of which may be counted within the eight-year minimum period of experience) he must have held one or more positions of professional responsibility. If his degree is *specifically* in agricultural engineering, agricultural mechanisation or a closely allied branch of pure or applied science, he will need to show that for at least two of the said five years he has been solely engaged in agricultural engineering or mechanisation. This category includes the person with a background, in one of the biological sciences who is engaged in the mechanisation of agriculture or horticulture or in agricultural engineering or mechanisation research.

A person with a degree in *some other* branch of engineering or an associated technology, may also be eligible for Fellowship provided that in that case *all five years* of the prescribed minimum period of professional responsibility must have been solely or mainly spent in the realm of agricultural engineering or mechanisation. At the time the candidate applies, he must show that he has gained for himself an established reputation.

The quality and extent of knowledge, experience and responsibility to be expected in a Fellow of the Institution are broadly covered by the EUSEC definition of a 'Professional Engineer'. This is quoted in the Institution's *Guide to Membership* as also are details of the Part IIB and III Regulations. A revised edition of the *Guide*, a companion set of *Special Notes for the Guidance of Candidates for Entry and Transfer to the Grade of Fellow* and a new booklet entitled *The Part III Review : Notes for the Guidance of Candidates* will shortly be available from the Secretary, free of charge.

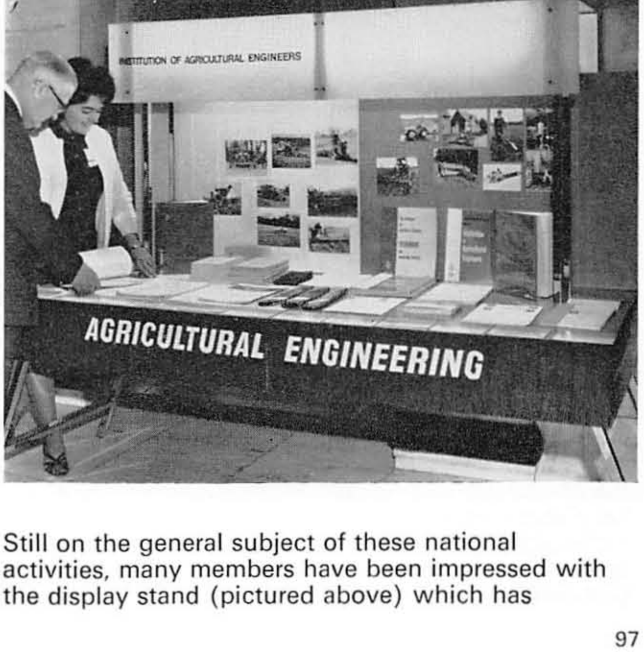
Session 1970-71

During the summer months the curtain comes down on most of the Institution's visible activity. But it would be a mistake to think that all is quiet back-stage as well.

By the time this *Journal* is being read, the ambitious two-day Joint Symposium sponsored by I Mech E and I Agr E in London on 6-7 October will have taken place. Some twenty papers will have been given by an international cast of speakers on the theme 'Agricultural and Allied Industrial Tractors' and reports of its proceedings will feature in one or more issues of the *Journal* in 1971.

The National College at Silsoe, as well as being a hive of South East Midlands Branch sessional activity has more than once housed the Institution's National Meetings. It will be doing so again on Tuesday 30 March 1971 when the I Agr E Spring National Meeting will offer a day of papers and discussions on 'The Selection and Development of New Products'. The programme convenor will be the Institution's Immediate Past President, Theo Sherwen.

Be sure also to make a firm note of Thursday 6 May 1971, the date of the Institution's Annual Conference, AGM and Annual Dinner in London. The conference programme will cover 'Engineering Aspects of Green Crop Conservation' and is being organised by Gordon Shepperson of NIAE, Silsoe.



Still on the general subject of these national activities, many members have been impressed with the display stand (pictured above) which has

B

figured at some recent events. It may not be generally known that this was generously presented by the Castrol Organisation a few years ago, to the Institution and AMTDA Ltd in recognition of the work of these two organisations in the field of agricultural engineering education and training.

All over the country, Branch Committees have been busy planning a host of events designed to woo members away from home, hearth and box this coming winter. By now every member should have received his pocket booklet giving dates, places and times of National and local activities. It can never be said often enough how important it is to turn out and support these activities. They constitute the steady heart-beat of the Institution and provide evidence, as nothing else can, of the Institution at work for the benefit of the membership and the industry. Not least, they provide a meeting point at which the visitor might discover a wish to join the Institution's ranks.

MinTech Committee on Terotechnology

During April last, the then Joint Parliamentary Secretary to the Ministry of Technology, Dr Ernest Davies, announced the formation of a Committee on Terotechnology. In answer to a Parliamentary question asking when the report of the Working Party on Maintenance Engineering was expected, Dr Davies replied that the report was about to be published. Its main recommendation was that a Committee should be set up to advise the Ministry of Technology on actions necessary to create a greater awareness of the importance of the subject.

Discussions within the Ministry and with outside interested parties had indicated that the scope of the subject was far greater than that which was generally understood by the term 'maintenance engineering'. It included, for example, installation, commissioning and replacement of plant, machinery and equipment, feedback to designers, and management techniques such as investment appraisal.

'In order to focus attention on the importance of of this technology' concluded Dr Davies 'it was considered advisable to utilise a name reflecting the wider concept now envisaged. The word *Terotechnology* has therefore been adopted and the Committee will be known as the Committee on Terotechnology'.

At the first meeting of the abovementioned Committee it was realised that the problem areas defined in the report would already be known to various professional bodies, including this Institution.

Accordingly, a Professional Activities Sub-Committee was set up 'to determine the scope of such activities and to make recommendations to the main Committee on how it might help'. The Committee hopes that the Institution and its members will come forward with information and suggestions where agricultural engineering and mechanisation falls within the field of terotechnology.

MinTech obviously feel that a considerable effort on the part of the new Terotechnology Committee is justifiable and will welcome the assistance of professional bodies who have already been active in promoting awareness and understanding of the problems involved.

Members interested or engaged in this specialised field are invited to write to the Institution, giving their views or suggestions.

Operators' Instruction Manuals

A Study Group has been set up by the Institution's East Anglian Branch under the Chairmanship of Mr T. B. Dingle, to attempt to review current farm machinery instruction manuals and to suggest a suitable specification to assist writers of these books in the future.

This idea was prompted by the publication in the Spring 1970 issue of this *Journal* of the paper 'Ergonomics in the Development of Operational Skills' by Messrs. H. T. Lovegrove and D. J. Evans, who said that farm machinery manufacturers could do a great deal more to make operators' instruction manuals more useful. They said that there was a great variation in the content, format, layout and durability.

Any views on this subject would be appreciated by this Study Group and should be sent to the Secretary, Mr J. B. Mott, County Education Office, County Hall, Norwich NOR 49A.

Forthcoming Events For Your Diary

Miss Jean Wilding, well known editor of *Farm Engineering Industry*, has taken a cudgel to the Institution. *Forthcoming Events* in the Summer 1970 issue of the *Journal*, complains Miss Wilding, is virtually identical in content to the regular feature entitled *For Your Diary* in *FEI*.

And so it is. Most industrial publications carry this class of information somewhere in their columns. Where more than one periodical is to be found within a specialised branch of industry, such as agricultural engineering, it is difficult for strictly calendar information to be made to appear differently in each case. It is the job of the Institution to report available and relevant calendar information to its members, and this it will continue to do.

The Institution regrets the close resemblance of *Forthcoming Events* in the Summer 1970 *Journal* to the well-conceived *FEI* feature; the latter was first in the field with its particular information and the Institution has accordingly restyled its own feature in deference to the honourable code of *editio princeps*.

Cover Story

Readers seem to like the pictorial front covers that are now a regular *Journal* feature. On the front of the Summer 1970 issue (described by one reader as an all-electric model) we reproduced part of Figure 11 from *Farm Electrification Handbook No. 18* by kind permission of the Electricity Council. However, as Mr Ron Bayetto points out (see *Viewpoint* on Page 132) much credit is due to Matthews and Yates Limited from whom the diagram originated.

Taking the matter even further, we made the agreeable discovery that the gentleman in Matthews and Yates, Mr A. Caton, who actually created the diagram, is an Institution member. Thus does the wheel poetically turn full circle. The Institution, as we always suspected, is everywhere! □

NEWSDESK

Tractor Cabs and Farm Safety

Congratulations to the Ministry of Agriculture, Fisheries and Food on bringing out a really clear leaflet about the compulsory fitting of safety cabs or frames to tractors. Entitled 'Your Questions Answered' the leaflet lists in question and answer form the main points for guidance, but wisely states that it 'does not purport to be an authoritative interpretation of the Agriculture (Tractor Cabs) Regulations 1967'.

As from 1 September 1970, these important Regulations made it an offence to sell or let on hire for use in agriculture a new wheeled tractor weighing 11 cwt or more in its basic form, i.e. without water, fuel or lubricating oil, unless it is fitted with an approved safety cab, or frame. Existing tractors have until 1 September 1977 to be so fitted, although the Ministry think it advisable to do it now. An approved safety cab, or frame, must be a rigid structure, tested under British Standard BS 4063: 1966 and approved by the Ministry. The approval mark, as shown opposite, is a crown inside a triangle. It must be fixed to the main structure in a clear, legible and permanent manner, and in a prominent position. There must also be supplementary marks affixed as near as possible to the approval mark, again in a permanent manner, and these must show the make and serial number as well as the make and model of tractor for which it is approved. An approved safety cab or frame may be fitted *only* to the make and model of tractor for which it is approved.

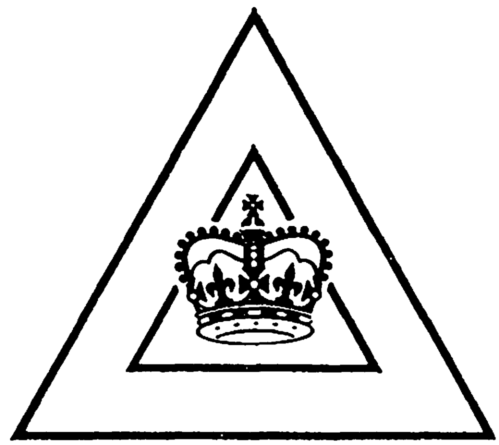
The person responsible for seeing that an approved safety cab, or frame, is fitted at the time of sale is the person who sells it, e.g. the dealer or agent. The Ministry stress the importance of following the manufacturers' fitting requirements and specifications exactly. The use of wrong bolts, for example, could be dangerous and invalidate the approval. It is in order for cladding to be added to an approved safety frame to convert it to a cab, provided this is done by the *user*. It must not be carried out by the dealer or agent on behalf of a customer before sale or letting on hire, because it would not then be an approved cab. The addition of cladding by the user can only be by strapping it to the frame; any cutting, drilling or welding of the frame would cause it to be no longer approved.

Employers and farm-workers each have clear responsibilities. The employer must not allow a worker to operate a tractor not covered by these Regulations, and a worker must refuse to operate it, unless it is fitted with an approved safety cab or frame. The only exceptions are as follows:

1 During use in, or going to or from, a hop garden, hopyard or orchard, if it is not practicable to use a tractor with a cab during operations therein.

2 When used inside a building in which, due to design, it is not practicable to use a tractor with a cab,
or
when working in close proximity to such a building during the course of an operation inside that building,
or
going to or from operations inside such a building.

A worker must report to his employer whenever a



tractor driven by him overturns, or if the safety cab, or frame, or its fittings are damaged from any cause, or if the windscreen wiper (when fitted) becomes defective. It then becomes the employer's responsibililty to establish whether the safety frame, or cab, is damaged or defective to the extent that it no longer complies with the Regulations. This is the point at which expert agricultural engineering advice should be sought and the reputable dealer will no doubt see that it is available.

More Specialists Needed Overseas says FAO

'As more countries become increasingly industrialised there is a trend for the proportion of farmers to decrease.' This is one of the points made in a background paper on vocational training for farming and rural occupation presented to the World Conference on Agricultural Education and Training in Copenhagen from July 28 to August 8.

The paper also states that at the same time those whose occupations were linked with agriculture as technicians or specialists would increase in numbers. To transfer to a more developed economy, the people themselves had to become more specialised.

'The farmer is not only a worker, he is also a manager and should be given farm management training in order to derive maximum profit from his land,' the paper says.

Ways and means of establishing facilities for vocational training in rural areas are set out in the the paper which suggests broad outlines for staffing and curriculum planning. It insists that the best way to teach is 'learning by doing' and suggests centres should have a farm or a workshop for practical training for farmers and artisans. 'Vocational training not only involves the training of individuals for their future occupation or for their adjustment to a given environment, but also the awakening in young people a sense of responsibility towards their community and instilling in them the idea that a transformation is necessary before the community can meet the requirement of economic, technical, social and political development. Thus, vocational training involves both individuals and communities in the general development process', the paper concludes.

The World Conference on Agricultural Education and Training was held by the three UN agencies—the Food and Agriculture Organisation, the Educational, Scientific and Cultural Organisation and the International Labour Organisation.

Expansion Ahead at NCAE

The annual Commemoration Day and Presentation of Awards occurred at the National College of Agricultural Engineering, Silsoe, on 30 June, when Bachelor of Science degrees were awarded to 22 students. Postgraduate Certificates were awarded to 19 students from 10 different countries. The Principal Guest on this occasion was Professor W. H. Boshoff, Head of Department of Agricultural Engineering and Land Planning, Makerere University College, University of East Africa. Mr C. Culpin, as President-elect, represented the Institution of Agricultural Engineers; Mr U. G. Spratt, President of AMTDA and Mr L. V. Chivers, Vice President of AEA represented their respective Associations.

In his speech, Mr H. H. Dawson, Chairman of the College Governors stated that the College was keeping satisfactorily to its planned rate of expansion to a total of 200 students by 1974/75. Building work at present in progress was all part of this expansion—one of the new hostels having been donated by the Owen family as a memorial to the late Mr Ernest Owen. The Chairman stressed that there was an ever increasing need in the industry for men with appropriate training and outlook—it was not good enough merely to 'keep up with the Jones' if we were to survive as a nation and an industry; we must always be at least one move ahead. The number of Short Courses arranged by the College was increasing, and a total of 200 students had studied here during the year. Some 400 were expected in the next year.

Professor P. C. J. Payne, Principal of the College, mentioned three important factors which were likely to bring about an increase in the number of postgraduate students at the College. These were a rapidly improving facility for the study of Land Resource Planning, the introduction of a two year Masters degree involving a year's taught course at Silsoe followed by one year's research work overseas, and the proposed introduction in 1971 of a special Certificate course in 'Product Planning and Marketing in Agricultural Engineering'. Professor Payne also reported that the Council for National Academic Awards had approved certain changes in the undergraduate course—both in syllabus and in examination arrangements. One result of this had been a reduction in the number of examination papers taken by students in their final examinations. Finally the Principal mentioned the now active Silsoe Society—the College Old Students Association—which had held its first Annual Dinner this year, and hoped that those who had left the College and were not members would take this opportunity of keeping in touch.

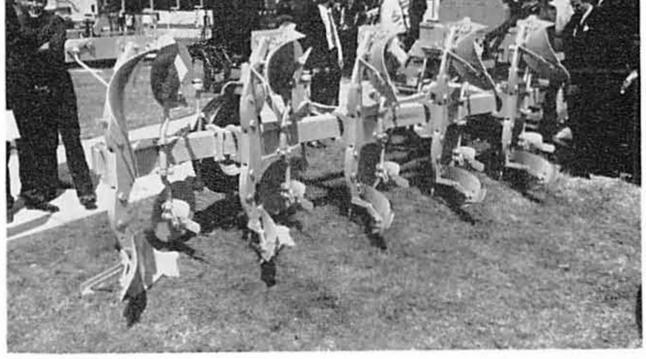
Professor Boshoff referred to the close association which had been formed between the College and and Makerere University College and welcomed the exchange of ideas and mutual involvement which was occurring in research projects. Such a link could do nothing but good.

Among those to receive special awards at the NCAE Commemoration Day Ceremony were Richard F. Gibson (*left*) who won the Davies Cup for the undergraduate with the best appreciation of agriculture. Next to him is Jeffrey B. Morgan receiving a hand-shake from Professor Boshoff, a smile from Professor Payne and the Skefko Trophy for the best Final Year student of Engineering Design. Other prize winners included John E. L. Boyd who received the Hunting Cup for the best Final Year student of Field Engineering and Glyn R. Davies who gained the Farm Buildings Association Prize for the best Final Year student of Environmental Control.

Newsdesk Special

Roving the Royal—an exclusive report for *Newsdesk* by D. J. Greig and K. A. Pollock of the University of Newcastle upon Tyne

The main demonstration at the 1970 Royal Show concerned one of agriculture's least attractive but most pressing problems—waste handling and disposal. In an exhibit organised by the Farm Buildings Centre and the R.A.S.E., one was able to inspect a broad range of slurry handling and storage equipment, watch a demonstration of three types of solid manure loading and spreading equipment, compare the working of three organic irrigation systems and, in the attractive M.A.F.F. display, study the research programmes in progress in Universities and other centres throughout the country. In order that this might be of lasting value, an informative pamphlet was prepared setting out the basis for planning a waste management system. In the treatment field, a number of firms exhibited their empirical adaptations of the aeration principle, and the Butyl Products Hydox digester was a highly commended Silver Medal entry.



The Dowdeswell reversible plough received the R.A.S.E. Burke Trophy at the 1970 Royal Show (photograph by Agricultural Press Ltd.).

The R.A.S.E. Burke Trophy for the best new implement went, however, to a more familiar item of farming equipment, a reversible plough, designed in this case by a local farmer, R. Dowdeswell, to operate as a mounted or semi-mounted implement behind a crawler with category 2 or 3 linkage. The four or five furrow unit is turned by a double acting hydraulic ram and may be held in an intermediate position for transport.

Also notable amongst the Silver medal entries were the Weimar two-row potato harvester, marketed by Johnson's (Engineering) Ltd., finding favour with the judges over the X-ray separation harvester, now manufactured by Root Harvesters Ltd.; the Moray bag-filling device for continuous operation with two outlets, working within Board of Trade limits; and the Taarup Unidry Grass Drying System. This system includes a single pass rotary high temperature drum, feeding a reciprocating piston press producing wafers from short chopped grass.

Grass drying was the subject of another of the field demonstrations which are such a valuable supplement to the static machinery displays. This year farmers were also able to see the Autotrack driverless tractor in operation, and note the accurate positioning of the equipment on successive circuits.

In the tractor field, emphasis was naturally placed upon the safety cabs which became a legal requirement on September 1, 1970. In general, the safety frame was incorporated in an all-weather cab, with some variation both in the type of cladding and the effort expended upon the elimination of vibration. Massey-Ferguson and John Deere showed contrasting approaches to the bare safety frame, the latter consisting of a simple, but massive, roll-over bar. The most impressive cab, however, was found on the Polish Ursus tractor, marketed by Maulden Engineering Co. Here some genuine attempt had been made at isolating the cab from engine vibration, giving a spacious working area fully enclosed by large glass panels, plus good access and an uncluttered floor. No doubt the next generation of British tractors will reflect the incorporation of a cab as an integral part of the design.

More than thirty years after the introduction of the original Rotolactor, rotary milking parlours appeared to be making a determined comeback. The new models, however, are designed for herds of 100 cows or less, to be milked by one man at the rate of between 50 and 100 cows per hour. As few as five stalls may be incorporated, so that the parlour rotates intermittently, allowing the operator to remain in one place. Identification is facilitated by presenting the cows broadside to the cowman, and Fullwood demonstrated their Tally Feed system of automatic metering of food, controlled by an individual plastic card. In combination with their 'Carousel' rotary parlour only one feeder is required for the herd. With the virtual elimination of walking, this routine job of parlour milking has been made not only more rapid but also less arduous, although the equipment may cost up to three times as much as an equivalent herringbone design.

The 'Royal' would not be complete without the livestock competitions and the events in the Grand Ring. Livestock entries were of high quality this year but numbers declined, in line with the trend of recent years.

Charolais cattle were accepted for the first time as a breed for judging, and at a subsequent sale up to 6500 gns. was paid for the heifers, most of which were destined to go abroad. Another 'first' was scored by the Guernsey breed who took the 'Burke' Perpetual Challenge Trophy for the best male and female champions in the dairy and dual purpose class, ousting the usual Freisian or Ayrshire victors.

A highlight in the main ring was the U.S.A. Mid-West State Fair, sponsored by Ford Tractor Operations Ltd., and featuring the world lassoo champion, trick riding, a chuck wagon race, Indian war dances and the first quarter horse sprint races staged in Britain. In a more conventional vein were the horse jumping, a falconry demonstration, and the tractor handling competitions.

As a new feature at this year's Show the R.A.S.E. organised a Machinery Advisory panel, to assist farmers in deciding on suitable machinery systems for their needs, prior to talking over the merits of individual machines with trade representatives. Although interest was restricted by a lack of publicity, many genuine enquiries were successfully discussed, and this service may become a regular feature of the Show.

It is to be hoped that this new departure, and the continued high attendance this year, will overcome the pessimism expressed by many machinery exhibitors over the value of their investment at the Show. Concern over increased costs and the continued depressed state of trade has cast some doubt amongst the machinery exhibitors over the prospects of another successful Show in 1971. □

Dates for your Diary in 1971!

THE I AGR E SPRING NATIONAL MEETING (SESSION 1970-71)

A Whole-day Conference will be held on:

SELECTION AND DEVELOPMENT OF NEW PRODUCTS

(Programme Convenor: T. Sherwen, C Eng, FI Mech E, FI Agr E, MSAE)

at the National College of Agricultural Engineering, Silsoe, Bedford
on Tuesday 30 March, 1971

THE I AGR E ANNUAL CONFERENCE (SESSION 1970-71)

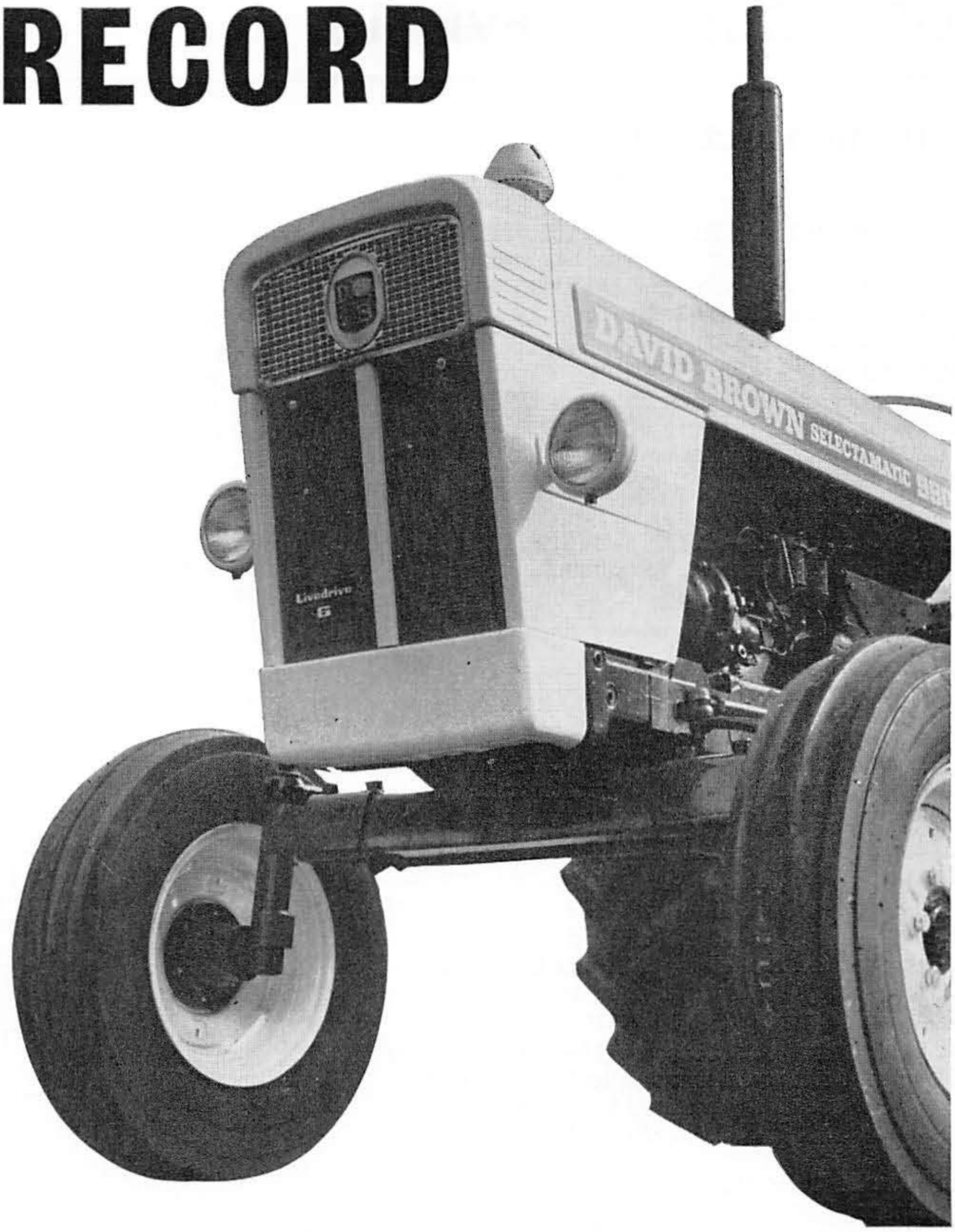
A Whole-day Conference will be held on:

**ENGINEERING ASPECTS
OF GREEN CROP CONSERVATION**

(Programme Convenor: G. Shepperson, BSc (Agric), FI Agr E)

at The Institution of Mechanical Engineers, 1 Birdcage Walk, London SW1
on Thursday 6 May, 1971

JUST FOR THE RECORD



Few tractor manufacturers anywhere in the world can match the David Brown record of pioneering achievement in tractor manufacture and development. Here are some of the more significant examples:

★ World's first farm tractor with hydraulic lift and converging 3-point linkage—1937.

★ Two-speed power take-off—1948.

★ High-speed direct injection diesel engine for farm tractors—1949.

★ Traction control (implement weight transfer)—1953.

★ 6-speed (1948) and 12-speed (1966) gearboxes.

★ All-purpose tractor hydraulic system with single lever control—1959.

★ Dial-selection tractor hydraulic system—1965.

★ Full hydrostatic power steering –1969

When it comes to pace-setting, everybody watches David Brown, the all-British company with the flair for leadership.

DAVID BROWN TRACTORS

(Sales) Limited,
Meltham, Huddersfield, England.

THE QUEEN'S AWARD TO INDUSTRY

A SUBSIDIARY OF THE DAVID BROWN CORPORATION LIMITED

FORTHCOMING EVENTS

Institution Activities

NOVEMBER 1970

WED. 4 at 19.30—WREKIN SUB-BRANCH
Development in Tractor Electrical Systems by H. Harrison of Joseph Lucas Ltd, to be held at The Small Hall, Shrewsbury Technical College, London Road, Shrewsbury.

TUES. 10 at 19.00—NORTHERN BRANCH
Control of Livestock Environment by Dr Smith, Lecturer in Animal Production, University of Newcastle upon Tyne, to be held at the Agricultural Department, University of Newcastle upon Tyne.

WED. 11 at 19.00—SCOTTISH BRANCH
Safety and Comfort by R. M. Chambers & T. Tyler of Massey-Ferguson (UK) Ltd, to be held at The Moncrieff Arms Hotel, Bridge of Earn, nr Perth.

THURS. 12 at 19.30—SOUTH WESTERN BRANCH
Mechanised Handling of Slurry and Farmyard Manure Disposal by M. Williams, Market Analyst of Howard Rotavator Co Ltd and G. P. Hunt, Technical Representative of Wright Rain Ltd, to be held at the Exeter Technical College, Exeter.

WED. 18 at 19.30—EAST ANGLIAN BRANCH
50 *Years of Farm Machinery* by C. E. Westrip to be held in Ipswich (exact venue to be announced).

WED. 18 at 19.45—WESTERN BRANCH
Aerobic Treatment of Farm Effluents by D. A. Young, of Butyl Products Ltd, to be held at The Bath Arms Hotel, Warminster.

THURS. 19 from 10.45 to 16.15—EAST ANGLIAN BRANCH. Annual Conference to be held at the Norfolk School of Agriculture, Easton, Norwich. *VEGETABLE HARVESTING, PROCESSING AND STORAGE*
Speakers: J. Love, Horticulturist, J. Sainsbury Ltd; S. Johnson, Ransome, Sims & Jeffries Ltd; J. S. Robertson, Vegetable Mechanisation Specialist, N.A.A.S.; J. Waterfall, Farmer specialising in vegetables.

MON. 23 at 19.30—SOUTH EAST MIDLANDS BRANCH
Current Developments in Engineering Materials by B. S. Hockenhull, of Cranfield Institute of Technology, Cranfield, Bedford, to be held at the National College of Agricultural Engineering, Silsoe, Bedford.

FRI. 27 at 19.30—YORKSHIRE BRANCH
An Examination of Mechanisation Costs by R. W. Helme of the Ministry of Agriculture, Fisheries and Food to be held at the Griffin Hotel, Boar Lane, Leeds.

MON. 30 at 19.30—WEST MIDLANDS BRANCH
Alternators for Agricultural Machinery by R. Bater of Joseph Lucas Limited to be held at Massey-Ferguson Training Centre, Stareton, Nr Kenilworth.

DECEMBER 1970

TUES. 1 at 19.00—NORTHERN BRANCH
Soil Profiles—Their Structure and Drainage by G. D. Ashley, Soil Survey of England and Wales, to be held at the Agricultural Department, University of Newcastle upon Tyne.

WED. 2 at 19.30—WREKIN SUB-BRANCH
Future Developments of the Diesel Engine in Agriculture by L. Lakin of Perkins Engines Limited, to be held at The Sanders Hall, Staffordshire College of Agriculture, Rodbaston, Penkridge, Stafford.

THURS. 10 at 19.30—MERSEYSIDE SUB-BRANCH
The Work of the N.I.A.E. Scottish Station by a member of the staff, to be held at David Brown & Co Ltd, Albion Street, Leigh.

THURS. 17 from 10.00 to 16.00—EAST MIDLANDS BRANCH. Annual Conference to be held at The School of Agriculture, Sutton Bonnington, Loughborough. *MAKE THE MOST OF YOUR GRASS.* Papers by: C. Culpin, D. J. B. Calverley, Dr J. H. B. Prescott, J. E. Moffitt—Chairman.

JANUARY 1971

MON. 4 at 19.30—WEST MIDLANDS BRANCH
Mechanical Feeding of Livestock by R. G. Mortimer of Harper Adams College, Newport, Salop, to be held at The Mid-Warwickshire College of Further Education, Warwick New Road, Leamington Spa.

TUES. 12 at 19.00—NORTHERN BRANCH
E.E.C. and Farm Machinery by L. K. Davies, Acting General Commercial Manager, Massey-Ferguson (UK) Ltd, to be held at the Beaumont Hotel, Hexham.

WED. 13 at 14.00—SCOTTISH BRANCH
Visit to Leyland Motors (Scotland) Limited, Bathgate, West Lothian. Factory tour—working demonstrations—discussion.

WED. 13 at 19.30—WREKIN SUB-BRANCH
The Selection and Marketing of Agricultural Machinery by P. F. C. Scott of Massey-Ferguson (UK) Ltd to be held at The Harper Adams College, Newport, Salop.

THURS. 14 at 19.30—EAST MIDLANDS BRANCH *Future Trends in Farm Buildings* by G. Benoy, Architect, to be held at the Nottinghamshire College of Agriculture, Brackenhurst, Southwell.
FRI. 15 at 20.15—EAST ANGLIAN BRANCH *Think Before you Mechanise* by G. L. Hunt, Farm Mechanisation Adviser, N.A.A.S.; to be held at The Scole Inn, Diss, Norfolk.
THURS. 21 at 19.30—SOUTH WESTERN BRANCH *Making Good Use of the Bank* by N. Coward, General Manager's Assistant, The Midland Bank Ltd, to be held in Exeter (exact venue to be announced).
THURS. 21 at 19.30—MERSEYSIDE SUB-BRANCH *Turf and Turf Maintenance Equipment* by E. Staniforth, Assistant Managing Director of 'Sisis' of Macclesfield to be held at the Lancashire College of Agriculture, Myerscough Hall, Bilsborrow, Preston.
MON. 25 at 19.30—SOUTH EAST MIDLANDS BRANCH. *The Basic Principles of Waste Treatment* by A. B. Wheatland, of the Water Pollution Research Laboratory, Stevenage, to be held at the National College of Agricultural Engineering, Silsoe, Bedford.
WED. 27 at 19.30—EAST ANGLIAN BRANCH *Farm Machinery Design and Testing* at Ransome, Sims & Jeffries Ltd, Ipswich.
FRI. 29 at 19.30—YORKSHIRE BRANCH *FORUM—The Problems of the Farm Machinery Dealer.* G. Ayres of Appleyard of Wetherby Limited. J. E. D. Neall of International Harvester Company of Great Britain Limited. J. R. Fishwick—a farm machinery user. To be held at the Askham Bryan College of Agriculture and Horticulture, Askham Bryan, York.

Other Activities

NOVEMBER 1970

WED. 4/FRI. 6—ASCE & ASAE
Specialty Conference on Irrigation and Drainage to be held at Deauville Hotel, Miami Beach, Florida, USA.
FRI. 6/TUES. 10—AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES
First National Biological Congress, to be held at Detroit, Michigan, USA.
TUES. 10/FRI. 13—ASAE NATIONAL MEETING
National Irrigation Symposium to be held at Nebraska Center for Continuing Education, Lincoln, Nebraska, USA.
WED. 11/SUN. 15—EIMA 70
International Agricultural Machinery Exhibition to be held at the Fair Centre, Bologna, Italy.
SAT. 21 from 10.00 to 16.00—ASSOCIATION OF AGRICULTURE. *Agriculture in the Countryside.* A Conference on conservation, amenity and education to be held at London School of Economics, London.

DECEMBER 1970

TUES. 1/THURS. 3—NATIONAL FERTILIZER SOLUTIONS ASSOCIATION (USA)
Annual Convention and Equipment Exhibition to be held at Kiel Auditorium, St Louis, Mo.
MON. 7/FRI. 11—ROYAL SMITHFIELD SHOW AND AGRICULTURAL MACHINERY EXHIBITION
To be held at Earls Court, London.
MON. 14/WED. 23—ASSOCIATION OF ENGINEERS AND ARCHITECTS IN ISRAEL
Second World Congress of Engineers and Architects dedicated to the theme of Dialogue in Development. To be held at the International Technical Co-operation Centre, Tel-Aviv, Israel. □

IT PAYS TO CHECK

with the organizers whether there has been any change, addition or cancellation to the Institution's published programme. The following officers will gladly keep you informed of sessional activities in their areas.

NATIONAL ACTIVITIES
Asst. Secretary (Publicity):
H. N. WEAVERS
The Institution of Agricultural Engineers
Penn Place, Rickmansworth, Herts.

EAST ANGLIA
Branch Hon. Secretary:
J. B. MOTT, MI Agr E
County Education Office, County Hall
Norwich, NOR 49A

EAST MIDLANDS
Branch Hon. Secretary:
R. D. S. BARBER, BSc, ND Agr E, MI Agr E
The Farm Institute, Caythorpe Court
Nr. Grantham, Lincs.

MERSEYSIDE
Sub-Branch Hon. Secretary:
G. R. HOBBS, ND Agr E, MI Agr E
12 Greenacres Drive, Garstang,
Preston, Lancs.

NORTHERN
Branch Hon. Secretary:
R. COWAN, MI Agr E
Northumberland College of Agriculture
Kirkley Hall, Ponteland, Newcastle upon Tyne

SCOTTISH
Branch Hon. Secretary:
G. C. KERR, AI Agr E
Thirlestane, Burnhead Road
Blairgowrie, Perth

SOUTH EAST MIDLANDS
Branch Hon. Secretary:
G. SPOOR, BSc, (Agric), MSc (Agr Eng), MI Agr E
National College of Agricultural Engineering
Silsoe, Beds.

SOUTH WESTERN
Branch Hon. Secretary:
C. R. CLARKE, MI Agr E
15 Spurway Road, Hay Park
Tiverton, Devon

WESTERN
Branch Hon. Secretary:
H. CATLING, ND Agr E, MI Agr E
Engineering Department,
Royal Agricultural College
Cirencester, Glos.

WEST MIDLANDS
Branch Hon. Secretary:
G. ROSE, ND Agr E, MI Agr E
5 Grange Gardens
Wellesbourne, Warwicks

WREKIN
Sub-Branch Hon. Secretary:
J. SARSFIELD, ND Agr E
Staffordshire College of Agriculture
Rodbaston, Penkridge, Stafford.

YORKSHIRE
Branch Hon. Secretary:
J. MAUGHAN, BSc, MSc, MI Agr E
48 The Hollows, Bessacarr
Doncaster, Yorks.

PUBLICATIONS

The following books, papers and data have been received or noted by the Institution.

Animal Health—by Irish University Press

Irish University Press editors and researchers have selected and grouped into subject sets basic sources of material on a wide range of significant subject areas from the whole of the nineteenth-century British Parliamentary Papers. The IUP Animal Health set contains extensive material on animal diseases and on the development and organization of the dairy and livestock industries during a period when they experienced rapid growth and transformation. The set is useful for research and project work on such topics as animal husbandry, the control of animal diseases, the history of the dairy and livestock industries, and agricultural economics and marketing.

The price is quoted as US $396, covering four volumes. Orders and enquiries should be addressed to Irish University Press, 141 Thomas Street, Dublin 8, Ireland.

Cereal Grains for Sheep—by the Livestock Branch, Department of Agriculture, South Australia.

The imposition in Australia of quotas on the delivery of cereal grains to silos has caused many growers to contemplate feeding of stored grain to livestock. This bulletin deals with the feeding of grain to sheep. Economic considerations are discussed and the mechanics of feeding are outlined, including precautions to be taken.

Listed as Extension Bulletin No. 10.70 the bulletin is obtainable from the Department of Agriculture, GPO Adelaide, South Australia.

Dictionary Catalogue of the National Agricultural Library (USDA) 1862–1965—published by Rowman and Littlefield, New York.

Claimed to be the most comprehensive agricultural catalogue in the world, the Dictionary Catalogue includes author, title and subject cards arranged in a single alphabet for all books and journals added to the Agricultural Library collection from 1862 to 1965. The Catalogue should assist bio-agricultural researchers throughout the world to determine, without delay, published information available in the National Agricultural Library. Subject fields covered include agricultural engineering, animal science, forestry, pesticides and pest control, plant science, soils, fertilisers and soil conservation, among many others.

Orders and correspondence should be addressed to Rowman and Littlefield, 84 Fifth Avenue, New York, NY 10011, USA.

Effect of Overwinter Decomposition on the Strength of Cotton Plant Residues—by F. E. Fulgham, J. W. Jones and R. F. Colwick.

This paper was produced for the Agricultural Engineering Research Division, Agricultural Research Service, USDA, in co-operation with the Mississippi Agricultural Experiment Station as a contribution to a Regional Research Project. Cotton plant residue, a waste product of the production system, must be managed so that it interferes as little as possible with the next crop. Because there is no commercial use for cotton stalks, they must either be removed from the field or treated in situ. The most common method is to cut or shred the stalks mechanically after harvest, letting them deteriorate before planting the next crop. Soil micro-organisms will speed the decaying process if the residue is incorporated into the soil. The study in this paper was designed to determine the relationship of residue size, plant section and depth of soil incorporation to the rate of decomposition in two different soil types.

Enquiries concerning this paper should be addressed to the United States Department of Agriculture, Agricultural Research Service, Beltsville, Maryland 20705, USA.

Evaluation of Distribution from Granular Insecticide Applicators—by D. L. Reichard and O. K. Hedden.

This paper was produced for the Agricultural Engineering Research Division, Agricultural Research Service, US Department of Agriculture, the authors being USDA Agricultural Engineers. The paper describes a study that was made of the linear distribution of granules dispensed by pesticide application equipment. US 20/40-mesh attapulgite clay was used as a standard granule for most of the measurements, although a few trials were made with other granular materials. The amount of grinding of granular material dispensed by the applicators was also investigated.

Enquiries concerning this paper should be addressed to the United States Department of Agriculture, Agricultural Research Service, Beltsville, Maryland 20705, USA.

Evenness of Spread of Spinner Broadcasters—by H. J. Burema, and **Field Drying of Hay and Wheat**—by I.G.M. Bruck and E. van Elderen.

Listed as Research Reports Nos. 1 1970 and 2 1970, respectively, the above papers are published by the Institute of Agricultural Engineering and Rationalization, Wageningen, The Netherlands. Details of availability should be addressed to Instituut voor Landbouwtechniek en Rationalisatie, Dr S. L. Mansholtlaan 12, Postbus 43, Wageningen, The Netherlands.

Housing Sheep—by the Farm Buildings Centre

A completely revised and expanded edition of the Farm Buildings Centre's report of sheep housing was published recently. It has been prepared by the FBC Technical Advisory Panel for Housing for Sheep who had compiled and written the original report published in 1967. The Panel felt that considerable experience had been gained since the first edition was published and that a full revision was needed. The latest report includes chapters on Sheep Housing as an Aid to Management; Housing Design and Construction; Economic Aspects; Problems of Disease; Feeding and Managenemt; In-wintering of Hill Sheep and Indoor Finishing of Hill Lambs. All quantities have been expressed in SI units with approximate imperial equivalents in brackets.

The report is published as FBC Report 13 and is available from The Farm Buildings Centre, NAC, Kenilworth, Warwicks, CV8 2LG at a cost of 10/- post free.

Industrial Aerodynamics Abstracts—by British Hydromechanics Research Association.

The recent growth of research into and publication of papers on problems in the field of non-aeronautical aerodynamics has led, with the support of the National Physical Laboratory, Teddington, to the production of industrial aerodynamics abstracts in order to give engineers and scientists in this important area the facility to remain aware of all developments. Six issues are to be produced in each volume which will run from January to December of each calendar year. The first two issues of 1970 have already been printed.

The annual subscription price is £20 (United Kingdom); £29 7s. 6d. (Elsewhere). Orders and enquiries should be addressed to The British Hydromechanics Research Association, Cranfield, Bedford.

Metrication—Three Films from the Central Film Library.

Aimed primarily to assist engineering companies, the following films are available for hire from the Central Film Library: UK 1994 Planning Metrication (17 minutes in colour); UK 1995 Phasing-in Metric Design (15 minutes in colour); UK 1966 Metric Production and Inspection (14 minutes in colour).

Metrication in Agriculture—by the Agricultural Development Association.

This booklet explains metrication in simple terms specifically for farmers, with the object of helping them to plan the changeover. In addition to describing the use of the new units of measurement, it devotes a section to the impact of metrication on buildings, where opportunities for standardisation are being taken.

Listed as Farmers' Report No. 3, the booklet is available, post free, at 4/- per single copy; 25 copies at 3/6 each or 200 copies at 3/3 each from the Agricultural Development Association, Cliftonfield Shipton Road, York.

Span Tables for Ridged Farm Portals in Solid Timber—by H. J. Burgess, V. C. Johnson and C. J. Mettem.

The tables are the outcome of one of the most ambitious structural design projects ever undertaken by the Timber Research and Development Association. They enable designers to select portal member sizes instantly for a range of buildings from 20 to 50 metres span with eaves heights ranging from 0·3 to 0·6 times the span. The tables relate to reference designs provided in TRADA Standard Design Sheets Nos. 133 and 134 which are bound into the publication as part of the illustrations.

Published as Information Bulletin E/IB/17, the tables are available at a cost of £1 (TRADA members 15/-) from the Timber Research and Development Association, Hughenden Valley, High Wycombe, Bucks.

NIAE Newsletter by The National Institute of Agricultural Engineering, Silsoe, Bedfordshire.

Research work on some projects at NIAE may proceed over long periods and there often have to be delays before the results can be published. Thus, it is desirable that industry should be kept informed of the activities of the Institute in order to foster close contact with industry. The Institute hopes that this need will be met by regular publication of a Newsletter, No. 1 of which was published recently.

Research projects described in this first issue include field trials of the Brussels sprouts harvester, automatic feeding of dairy cows, comparison of machines for cutting and conditioning grass, weighing devices, automatic control of continuous flow grain driers, well-based bins and the animal-drawn toolbar. Tests for manufacturers from January 1968 to December 1969 by the Tractor and Machine Performance Division are listed, as are some recent NIAE Reports and other items of Institute news.

Enquiries about the Newsletter and its availability should be addressed to the Information Division, National Institute of Agricultural Engineering, Wrest Park, Silsoe, Bedfordshire.

Pressure Distribution and Risks for Compaction in Agricultural Soils—by Birger Danfors.

This bulletin deals with the risks of causing lasting soil compaction, particularly in the sub-soil, through the use of heavy vehicles and machinery in agriculture. The report is based on comprehensive studies of the relevant literature and visits to a number of European research centres working on problems of soil management and soil compaction. This represents the first stage in an investigation planned to cover several years, which will be carried out by the Swedish Institute of Agricultural Engineering and will deal with weight and wheels of machinery or vehicles in relation to the risks for compaction, leading to lasting damage in the soil. The intention is to determine limits within which the maximum weight should be kept under different conditions with regard to different factors so that lasting damage to the soil can be avoided and the best economic results achieved.
Enquiries concerning this bulletin should be addressed to the Swedish Institute of Agricultural Engineering, Meddelande nr 333, Sweden.

The Reclamation, Development, Usage and Management of Vleis and Other Forms of Wet Land by P. R. Hill.

This paper formed part of a symposium on the vleis of Natal organised by the Natal Branch of the South African Institute of Agricultural Extension in May 1970.

The author points out that a wide range of vlei conditions occur in Natal, with soils too wet, seasonally or perennially, for optimum productivity of timber, grass or crops. A study is made of soil forms with their characteristics and their distribution and the resulting information is intended to serve as a guide to land capability and to indicate what treatments must be given if the best response is to be obtained from the soils.

Please turn to next page

Publications—*from previous page*

Selected Abstracts of Czechoslovak Agricultural Engineering Literature by the Research Institute of Agricultural Machinery, Prague.

Vol. 1 No. 1 of Selected Abstracts of Czechoslovak Agricultural Engineering Literature was published recently. They will be issued only occasionally for the time being but publication at regular intervals may be considered in the future. The Abstracts are to be sent free of charge to a limited number of foreign organizations (including I Agr E) with which an exchange of literature and information has been established. All articles may be obtained in microfilm or photoprint upon request under the exchange agreement.

Copies of Abstracts supplied in Vol. 1 No. 1 will be supplied free of charge to I Agr E members, on application to the Institution Secretary.

USDA Miscellaneous Publications by the Agricultural Engineering Research Division, USDA Agricultural Research Service.

Three publications have recently been received entitled 'Wagon Box for Drying Hay' (Plan No. 6071) 'Storage Bin for Fertilizer' (Plan No. 6072) ; and 'Hog House for Gestating Sows' (Plan No. 6074). Each of the above publications is available for sale, price US cents 5, from the Superintendent of Documents, US Government Printing Office, Washington DC 20402, USA.

BOOK REVIEW

Papers presented in the Panel on

Post Graduate Agricultural Engineering Education and Research in Latin America

Jointly sponsored by United Nations Development Programme UNDP/SF 80, executed by the Food and Agriculture Organisation of the United Nations.

This volume contains over 50 papers covering a wide variety of approaches to agricultural engineering in the context of the South American Continent. The authors are drawn from the United Kingdom, Canada and the USA as well as many South American and other countries. The subjects range from general approaches to the philosophy and role of agricultural engineering to the problems of financing and administering teaching and research in academic institutions concerned with agricultural engineering. A small number of papers deal with technical aspects of some agricultural engineering subjects, including simulation of hydrologic data and uniform grain drying.

The volume as a whole is a very valuable source of material to anyone who is concerned with the setting up of a new organisation for teaching and research in agricultural engineering. It is available, on loan, to I Agr E members on application to the Secretary.

J.A.C.G.

□

BSI NEWS

G. B. R. Feilden becomes Director-General of BSI

Mr G. B. R. Feilden, currently on the Council of The Institution of Mechanical Engineers and a Fellow of the Royal Society, assumed the leadership of the British Standards Institution on 7 September. Mr Feilden joined BSI as deputy director-general after being group technical director of Davy-Ashmore Ltd. for 7 years. An outstanding engineer and designer, he worked during the war years under Squadron leader (later Sir Frank) Whittle on jet propulsion and was a notable figure in the development of the industrial gas turbine in this country. He was responsible for the highly successful light industrial gas turbine produced by Ruston and Hornsby, examples of which are now installed in many countries.

His appointments in industry—he subsequently became managing director of Hawker Siddely Brush Turbines—led to much wider service at national levels. He has served on a number of Government and other committees, prominent among which was his chairmanship of the DSIR Committee on Engineering which issued the 'Feilden' Report. He is now a member of the Central Advisory Committee for Science and Technology, the Council for Scientific Policy and the Council of Industrial Design.

BSI's new director-general takes control at a significant stage in BSI's history. A more widespread realization of the key role of standardization in the application of advancing technology and its considerable influence on removing technical barriers to Britain's export trade has thrown a heavy burden on an Institution already intimately involved in the changeover to metric in this country. The development of BSI facilities to meet this pressure and the greater use of industrial skills and resources are among the many subjects which have a priority label.

The following information has been made available by the British Standards Institution.

British Standard for Steel Hooks

The British Standards Institution has published a revision of the Standard for forged steel hooks, BS 2903: 1970 *Specification for higher tensile steel hooks.* BS 2903 was first published in 1957, and represented an advance over the wrought iron and mild steel hooks of earlier Standards, being stronger by about a third. The 1970 revision represents a further advance in safe working load, by approximately a quarter.

The new Standard is in metric units. Safe working loads are in a constant geometrical ratio of 1.25 (see R 10 preferred number ratio, BS 2045) in conformity with other new lifting tackle Standards.

The following ranges of hooks are given:

Point hooks with shanks, having safe working loads from 0·4t to 63t.

Point hooks with shanks with increased internal diameter for small loads, 0·4t to 6·3t.

Point hooks with eyes for use with chain, 0·63t to 25t.

Point hooks with eyes for use with wire rope thimbles, 0·63t to 10t.

C hooks with shanks, 0·63t to 25t.

C hooks with eyes for use with chain, 0·63t to 25t.

A link is provided for use with the last mentioned range in order to enable it to accept a wire rope thimble.

The design principles are fully explained in an appendix and provision is made for a special hook designed according to this appendix but not included in the tables.

The proof loads on the hooks comply with the International Labour Organization table for proof loads, being twice the safe working loads up to 25t and thereafter on a reducing scale.

Manufacturers of hooks complying with BS 2903 may apply to BSI to use the Kitemark. This is a registered certification mark used only on licence from BSI and its presence on an item or its package is an independent assurance that it does comply with a British Standard.

Copies of BS 2903: 1970 can be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price by post, remittance with order, 21s (subscribers 18s).

British Standard for Chromium Plating on Plastics

The increasing importance of electroplated plastics has been recognized by the British Standards Institution with the publication of BS 4601 :1970 *Electroplated coatings of nickel plus chromium on plastics materials.*

No distinction is made in this specification between the types of plastics materials that are suitable for electroplating, since the adhesion of the coatings to the base materials, as well as the thermal stability of the composite article, is appraised by means of an appropriate thermal cycling test, selected according to the kind of temperature conditions which they are likely to encounter in service. To enable the coating to pass the thermal cycling test it may be necessary to use a substantial copper coating for the first electrodeposited layer.

When asking for plating to be carried out to BS 4601, the purchaser must also specify the service condition number denoting the severity of the conditions that the coating is to withstand. The Standard specifies in the form of classification numbers, which the purchaser may also state with his order, the types and thicknesses of nickel and chromium appropriate to service condition numbers 1–3. For service condition number 4, which represents service outdoors in exceptionally severe corrosive conditions, thicknesses and types of coating, thicker than those specified for service condition number 3, must be agreed between the purchaser and the supplier. Corrosion tests appropriate to each service condition number are also included in the Standard.

Copies of BS 4601 :1970 can be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price by post, remittance with order 12s (subscribers 10s).

Microbiological Examination of Milk Products

The comprehensive standard giving methods for microbiological examination of dairy products, the first two sections of which were published in 1968 as BS 4285—*Methods of microbiological examination for dairy purposes,* has now been completed by the publication of a Supplement in which methods for the examination of milk products are given. The Supplement covers, butter, hard cheese, soft cheese, processed cheese, cream, ice cream, yogurt, evaporated milk, sweetened condensed milk, dried milk, sterilized cream and other canned sterilized milk products.

The tests described give full details for colony count techniques, including preparation of samples, for all of the above products together with examination, where appropriate, for coli-aerogenes organisms and a number of other flora of particular relevance to certain products.

For sterilized products, details are included for general sterility checking, including sensory analysis.
This Supplement is intended to be read in conjunction with the standard itself since considerable cross-reference is made to the basic techniques used in the examination of liquid milk. Full details of the specialized media are given in a further appendix, and the supplement includes eight drawings illustrating specialized items of laboratory apparatus.

Supplement No 1 to BS 4285 is obtainable from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price 19s each. (16s to subscribers).

British Standard for Metric Grinding Wheel Flanges

A step forward in the safety of industrial grinding wheels is taken with the publication by the British Standards Institution of BS 4581 : 1970: *The dimensions of flanges for the mounting of plain grinding wheels.* The Standard covers flanges for use with grinding wheels having bores from 76.2 mm to 508 mm of the following types:

1. Plain wheels for fettling and sharpening.
2. Plain wheels for external cylindrical grinding (except centreless).
3. Plain wheels for surface grinding.

The requirements include the mounting dimensions of flanges, which are critical from the safety aspect. Additional precautions are recommended for the mounting and use of grinding wheels, which also help to ensure safety in operation.

The Standard is based primarily on Recommendation 666 of the International Organization for Standardization and has been published under the accelerated procedure for implementing ISO agreements in British Standards.

The ISO Recommendation includes both metric and imperial dimensions, but only the metric units are reproduced in BS 4581, in line with the U.K. policy of metrication. However, this Standard will provide complete interchangeability between grinding wheels, and flanges, except in respect of fastening threads, whether produced to the metric sizes or corresponding inch sizes in ISO 666.

Copies of BS 4581 : 1970: may be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price by post, remittance with order 10s (8s to subscribers).

Hydraulic Power, Transmission and Control Systems

A new British Standard BS 4575, *Specification for hydraulic power, transmission and control systems for industrial equipment,* now forms the basic Standard in the fluid power equipment field. It makes reference to other British Standards which relate to specific items of equipment and itself gives guidance to manufacturers and users of such equipment on their industrial applications in power, transmission and control systems. The aim of this guidance is to promote safety to personnel, productivity, adequate life of equipment, and to facilitate maintenance.

Care has been taken in the preparation to ensure that the Standard shall not in any way limit or inhibit the advancement of hydraulic or mechanical engineering.

The Standard, whilst applying to industrial applications, does not attempt to define this term because hydraulic equipment is finding an ever increasing diversity of uses, the majority of which will benefit from the application of the requirements of BS 4575.

Information is included on the construction and installation of the basic elements of a hydraulic system, component marking, and requirements for hydraulic system drawings and manuals. Certain of the requirements for information to be provided on drawings and for component marking, are included with a view to ensuring that it is easy to relate items on drawings to the corresponding components in the physical system. Methods of calculating pressure losses in pipes, valves and fittings are given in Appendices.

The Standard is based on metric units, but in order to provide the maximum of assistance at this stage of changing to the metric system in the United Kingdom, imperial equivalents of the metric units are also given for information.

Copies of BS 4575: 1970 can be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price by post, remittance with order 19s (subscribers 16s).

British Standard for Welding of Steel Castings

The subject of the repair of castings by welding has hitherto only been covered in British Standards by means of brief guidance in appendices to specifications for steel castings. The demand for something more substantive has resulted in the recent publication of the first part of a new British Standard: BS 4570: *Fusion welding of steel castings:* Part 1, *Production, rectification and repair—metric units.*

Although welding has long been established as part of the normal production process for steel castings, it is hoped that the new Standard will not only provide a means of specifying satisfactory procedures for good welding practice, but will give rise to some rationalization of the various existing requirements.

Part 1 relates the use of welding in normal production to rectify a casting before it is put into service, or to repair a casting that has been in service. It has been prepared primarily for manual metal-arc welding, but other processes can be used provided the requirements specified are suitably adapted for the particular process. A comprehensive range of steel castings is covered, including those in BS 3100 and BS 1504.

Because each location where welding is required demands individual consideration in relation to its particular characteristics, some clauses only give guidance and recommendations for determining the correct procedure. Also, there are no detailed requirements on inspection methods and acceptance levels as these have to be related to the requirements of the casting specification and service conditions.

Requirements for welder qualification are included, but in the case of welding procedure qualification approval tests are not required if a manufacturer can show that he has had sufficient experience of this type of welding. Such approval tests in any case are only required if specified in a relevant application Standard or if agreed between the contracting parties. Copies of BS 4570: Part 1 : 1970 can be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price by post, remittance with order 19s (subscribers 16s).

New British Standard for Hydraulic Hose

The British Standards Institution has published a new Standard for hydraulic hoses for use in such applications as engineering machinery, and earth moving vehicle hydraulic systems: BS 4586: 1970 *Spiral wire reinforced rubber hose and hose assemblies fitted with end couplings.*

The maximum allowable working pressure in this Standard are appreciably higher than in the other British Standards hitherto published for similar applications, viz. BS 3640: 1963 *Wire braid reinforced rubber hose, Type 1* and BS 3832: 1964 *Wire braid reinforced rubber hose Type 2.*

Three types of hose are specified in BS 4586:

Type 1 : Four-spiral light duty hose.

Type 2: Four-spiral heavy duty hose.

Type 3: Six-spiral heavy duty hose.

The requirements of this Standard are generally in line with those detailed in the Society of Automotive Engineers (USA) specifications SAE 100 R9, SAE 100 R10 and SAE 100 R11 which are widely used in numerous countries throughout the world.

Copies of BS 4586: 1970 can be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price by post, remittance with order 12s (subscribers 10s).

New Warning Plates for Heavy Vehicles—British Standard Promotes Road Safety

Motorists have been increasingly aware in recent years of the potential hazard presented by exceptionally long or slow-moving vehicles, including self-propelled agricultural or earth-moving machinery, particularly with regard to traffic following behind.

This hazard is now being tackled with the publication by BSI of BS AU 152: 1970 *Rear marking plates for vehicles,* which specifies the requirements for two distinct types of marking plates to be fitted to the rear of such vehicles so as to give adequate warning of their presence by day and night.

The Standard was produced at the request of the Ministry of Transport, who are now preparing legislation which will indicate how the plates are to be used on different vehicles.

The marking plates laid down in the specification are rectangular and consist of backing materials faced with reflex-reflecting and fluorescent materials and where applicable, black letters. Five types of plate are specified–three of them consist of various arrangements of a highly visual pattern composed of alternate diagonal stripes of red fluorescent material and yellow reflex-reflecting material and the other two consist respectively of one large plate and two smaller ones bearing the words "LONG VEHICLE" in black letters on a background of yellow reflex-reflecting material surrounded by a rim of red fluorescent material.

The Standard does not specify the materials of construction of the plates or their supports, but includes tests intended to ensure that plates made to comply with it will have adequate light reflecting properties, structural strength and resistance to weathering.

Manufacturers of rear marking plates complying with BS AU 152:1970 may apply to BSI to use the Kitemark. This is a registered certification mark used only on licence from BSI and its presence on an item or its package is an independent assurance that it does comply with a British Standard.

Copies of BS AU 152: 1970 are available from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price by post, remittance with order 14s (subscribers 12s).

British Standard will ensure safe Trolley Jacks

Hydraulic trolley jacks, which are in very wide use as a convenient method of lifting one end of a vehicle to a moderate height, are now covered by a British Standard Specification which will ensure the most rigorous levels of safety and reliability for those manufactured to comply with it.

In order to achieve this end, the Standard specifies loading tests, performance requirements and safety features as well as certain essential dimensions which not only affect the safety but also the usability of the jacks.

The Standard specifies trolley jacks, with capacities from 750 kg to 20·4 tonnes, of four types:

Standard trolley jacks; Kerb trolley jack; High lift type; and the Long reach type.

Manufacturers of trolley jacks complying with AU 154 may apply to the British Standards Institution to use the Kitemark. This is a registered certification mark used only on licence from BSI and its presence on an item or its packaging is an independent assurance that it does comply with a British Standard.

Copies of AU 154: 1970 can be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price by post, remittance with order 10s (subscribers 8s).

Chains and Chain Wheels for Agricultural and Similar Machinery

The British Standards Institution has published BS 2947: 1970 *Steel roller chains and chain wheels for agricultural and similar machinery,* which has been revised to bring it into line with the relevant Recommendation of the International Organization for Standardization, R 487—"Steel roller chains: Type S 32–S88 with their associated chain wheels".

Eight sizes of chains are standardized, with related chain wheels and attachments for use in such fields as agriculture, quarrying and mechanical handling.

The Standard gives dimensions and tolerances of chains and lays down chain measuring loads, chain breaking loads and recommended marking requirements. It is written in metric units but, to assist those in process of changing to the metric system, tables of related inch sizes are given in an appendix.

Copies of BS 2947: 1970 can be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price by post, remittance with order 14s (subscribers 12s). □

THE INFLUENCE OF CULTIVATIONS ON SOIL PROPERTIES

by N. J. BROWN, MI AGR E*

Presented at the Annual Conference of the Institution in London on 12 May 1970

1. Introduction

During the past half century the main tillage research in England was in experiments by Keen and Russell[1,2,3] at Rothamsted, and by Garner and Sanders[4,5] at Cambridge. Keen and Russell set out to check the validity of some of the reasons given for doing some cultivation operations; the conclusion drawn was that many of these reasons were invalid. From all the experiments over a period of 30 years, the general result was that the only cultivation significantly affecting final crop yield were those that achieved good control of all weeds, including seedlings. It was also shown that plants will tolerate a wide range of soil conditions. To-day, however, cultivation is no longer the only possible method of weed control, and soon it might be technically possible to control all weeds with herbicides. Supposing this was achieved, what general reasons remain for mechanically manipulating or cultivating the soil? The answer is not known, and while it is being sought farming practice must continue to use some of its traditional expertise in soil management. In specific situations cultivations have obviously been detrimental to crop growth, and some have been successfully studied in detail. As one example, the incidence and effects of compaction produced by traffic and implements have been investigated by Soane[6].

In the field, depending on soil type and soil conditions, some compaction is unavoidable: to exploit the power of a modern tractor by pulling an implement rather than through more direct means, the tractor wheels have to be heavily ballasted, and the load compresses the soil. Inevitably, some form of soil loosening will be needed, even where good yields are obtained by using herbicides and without cultivation to produce a seed-bed[7,8]. This is because the loaded wheels of spraying, sowing and harvesting machinery still have to traverse the land, often compacting the soil beyond those conditions that are conducive to good plant growth.

To control the plant root environment successfully a better understanding is needed of the functions of the physical properties of the soil forming this environment. During the past ten years, rigorous mathematical analysis of idealized soil physical systems has increased theoretical understanding of the mechanisms by which many of the physical processes occurring in the soil operate.[9,10,11,12] There are satisfactory equations describing many soil physical phenomena, but this type of knowledge is of no immediate benefit to the farmer, and the gap between theories and field behaviour seems to be widening instead of closing. This paper presents some ideas that may help a little to span the gap.

2. The raw materials

At the outset it is desirable to know something about the constitution of the material (soil) that has to be manipulated by cultivations.

The soil is a three-phase system, with a solid skeleton made of mainly mineral particles, and a fluid filled pore space within the skeleton. The fluid contents are 'soil water' and 'soil air', and though one replaces the other their total volume is not always invariant, especially in soils that shrink and crack on drying. This porous matrix is enriched by organic matter or humus and mineral salts. Individual particles of clay, silt, sand and stones, in different proportions, form the mineral part, and it is the variations in these proportions that give different soils different 'textural' properties. The individual particles are usually bound together (by water, inorganic and organic cements) to form crumbs and larger aggregates: the soil thereby acquires 'structural' properties. In general, cultivations will affect soil structure, but not soil texture, and the physical property of the soil most modified is the separation of the aggregates. The spaces between the solid particles are called pores, and the porosity is ratio of pore space to total volume.

3. Characterisation of soil conditions

Throughout the world, most experiments to evaluate different tillage operations have relied on the yield of test crops as a measure of the efficiency of a given operation. Results are inconsistent, and often contradictory. This is not surprising: crop yield depends on many other factors and interactions, including the weather during the experiment, which is outside the control of the experimenter. Also, the final soil condition after tillage is directly related to the initial condition, and this too may depend on the weather before the experiment started. It was thought that the limitations of this approach of the agronomist might be removed by including measures of soil conditions in terms such as bulk density, porosity, aggregate size and stability. Again the outcome has been singularly un-rewarding: there are no consistent correlations between crop performance and measurement of soil structure. The reason is that a plant root system does not respond to changes in bulk density or porosity unless they are associated with changes in water content, air content, soil temperature and root impedance. For a better knowledge and understanding of what tillage does to the soil it would seem desirable to measure these soil attributes and use plant response to determine which measured changes matter anyway. For any of the four factors the important aspect may enter as an Intensity, a Capacity or as a Rate function and Table 1 shows the relevant physical parameters suggested for measurement.

The relationship between tillage and the soil is a dynamic one, so none of the measurable parameters can be represented by a single value. Some are affected by hysteresis effects, so previous treatment and history must be considered too.

Some general predictions can be made about how each of the four factors might respond to tillage, mainly as a more detailed extension of a discussion started by Hawkins and Brown[13] on the effects of cultivations on the root environment.

4. The Four Soil Factors

4.1 Soil Water

Soil moisture is perhaps the most important of the four factors. Without water plant roots cannot absorb nutrients, and leaves will not remain turgid enough for the physiological processes that determine quantity and quality of growth[14]. Water also interacts strongly with the other three factors. Cultivation will affect the rate of infiltration at the surface, the redistribution and storage of the water within the profile and hence may affect drainage. It may also have some effect, direct or indirect, on evaporation and transpiration. Much depends on the geometry of the pore-space. The scale of the smaller pores, which hold water at higher tension, tends to be related only to the size of primary particles: the larger, more easily drained pores are formed by the natural aggregation of the particles into crumbs by soil

*Rothamsted Experimental Station, Harpenden, Herts.

TABLE 1

FACTOR	Variables (Time and Space)		
	Intensity	Capacity	Rate
1. Soil Water	Water potential	Volumetric moisture content	Permeability
2. Soil Air	Partial pressure of important components	Volumetric gas content	Diffusion coefficient
3. Soil Temperature	Temperature	Specific heat	Thermal conductivity
4. Root Impedance	Root pressure	Root volume	Root extension

microfauna, by shrinkage in unaggregated soils and by tillage. The proportion of smaller pores in a given volume of soil can be affected by compaction, but the effect of soil texture is predominant. It is expected that the unsaturated conductivity will increase with compaction and the saturated conductivity will increase with an increase in the proportion of large pores or a decrease in the bulk density of the soil.

Rain or irrigation water has to pass through the soil surface into the profile by a process called infiltration[15]. The water leaves the cultivated zone by drainage as liquid, and by transpiration or by surface evaporation as vapour. When cultivation loosens the soil and increases the total porosity and proportion of large pores then, to the depth of working, drainage and infiltration rates should be increased. The water holding capacity at low tensions might also be increased: at high tensions, for unit volume of soil it would be decreased.

The movement of water within the soil depends on differences in free energy expressed as a gradient of water potential in the soil. At a given point the moisture flux is the product of the potential gradient and the conductivity of the soil at that point. The conductivity itself depends upon the amount of water present, decreasing with decreasing moisture content. In dry soil (pF $>$ 4.2) liquid movement essential for plant growth ceases, but there will be some movement in the vapour phase: there are conflicting opinions about the importance of vapour flow[16]. It is therefore the capacity and energy functions of the water that condition the moisture status of the cultivated zone at any one time.

4.2 Soil Air

The two most important gases in the soil, oxygen and carbon dioxide, move through the soil from and to the atmosphere mainly by a process of diffusion. The rate of interchange depends on the concentration gradient developed by the respiration of plant roots and soil organisms[17] (taking up oxygen and liberating carbon dioxide), on the diffusion coefficient of the soil, and on the pore-space available for gas movement. In a soil with coarse aggregates and mainly large pores that are easily emptied by drainage the concentration of oxygen in the soil air will remain close to that in the atmosphere: oxygen will move freely into the soil. In soils where small pores predominate, retaining their moisture firmly, oxygen movement will be slower, concentration gradients will be much steeper, the oxygen demand of the plant roots may exceed the supply and absolute concentrations at the roots may reach undesirable values. By increasing the non-capillary pore-space and assisting drainage, tillage can have significant effects on the soil atmosphere[18,19].

4.3 Soil Temperature

Short wave solar radiation is the main source of heat energy to the soil. Heat is transported in the soil by conduction but long wave radiation and evaporation account for most of the loss at the soil surface. Both the heat capacity and thermal conductivity depend mainly on moisture content and bulk density, the soil mineral composition playing only a small part. Loosening the soil or decreasing bulk density and increasing drainage will decrease the value of both these properties. The rate of conductivity to heat capacity—the diffusivity—has no simple dependence on water content or structure, and it is the diffusivity that most directly influences temperature changes in space and in time within the soil. Hence, the effect of cultivation on soil temperature is extremely difficult to interpret. Many past measurements led to very misleading statements. Van Wijk[20] summarises a large amount of work on cultivation and soil temperature done by De Vries[21] and Van Duin[22]. Cultivation decreased the ratio heat flow in soil/heat flow in air for the diurnal temperature wave: during periods of increasing surface temperature cultivated soil was warmer at and near the surface, and cooler further down. The differences of surface amplitude were small for the annual temperature fluctuation, of the order of tenths of a degree centigrade for Western Europe. Deep cultivations may advance the season by one or two days.

For the diurnal variation, especially under clear skies, the looser cultivated soil has a greater temperature range—several degrees hotter at maximum, several degrees colder at minimum. The latter enhances the risk of damaging night frost.

4.4 Resistance to Penetration of Roots

Knowledge is meagre. Soil temperature, water content and air content may affect root behaviour, either by modifying the physical properties of the soil or by influencing the activity of the roots. The processes that may restrict root penetration are basically mechanical,[23] but the components cannot yet be defined. Even when they are, simulation of root action by some mechanical system is difficult. A root will modify its immediate surroundings when it extracts water, and through its flexibility it can exploit paths of least resistance. Fine metal probes, of the same size as roots, can be used as penetrometers, but comparisions of resistance experienced by probes and roots shows that the 'probe' resistance is several times as great as the 'root' resistance[24,25,26] —probably because the root is flexible.

Here, perhaps more than in any of the other three groups, the important problems may be on a micro-scale and and demand knowledge of what is happening within a few millimetres of a growing root. There are similar problems for other organisms in the soil, notably nematodes; there is already some experience for the dependence of nematode mobility on pore geometry and water content[27].

5. An Experiment

With the simplest possible design—Cultivations v. Uncultivated—an experiment was started in 1969 on light land at Woburn Experimental Farm. It was a preparatory year, intended to get the site as uniform as possible for use in 1970 and later. As many as possible of the parameters listed in Table 1, or referred to in the text, will be measured, both in space and in time. Some can be measured now, but others must await development of adequate techniques. With estimates of crop yields, it should be possible to answer two questions. First: what changes does cultivation produce in the physical environment of a crop? Second: which, if any, of those changes affect the final yield or ease of soil management?

6. Summary

Experiments that rely only on final crop yield to evaluate cultivation operations have not shown reasons for cultivating soil, other than weed control. However, even with efficient herbicides, soil compaction from traffic is inevitable and and mechanical loosening may well be necessary.

A *theoretical* knowledge of the mechanisms by which idealized soil physical systems function is of no immediate help to the farmer, and the semi-empirical approach of describing gross soil properties has not been rewarding.

A method is discussed of characterising soil conditions by measuring the variations that occur in the Intensity, Capacity and Rate functions of four soil physical factors: Soil Water, Soil Air, Soil Temperature and Mechanical Impedance to Roots and Shoots. These four factors have a direct influence on crop performance, and within the limits of existing knowledge, their response to cultivations is discussed within.

References

1. ANON. 'The relation of cultivation to crop yields'. *Rothamsted Experimental Station Annual Report*, 1936, 37-48.
2. RUSSELL, E. W. 'The relation between soil cultivations and crop yield'). *Rothamsted Experimental Station Annual Report*,1949, 130-147.
3. RUSSELL, E. W. 'The effects of very deep ploughing and of sub-soiling on crop yields'. *J. Agric. Sci.*, 1956, **48** (2), 129-144.
4. GARNER, F. H. and SANDERS, H. G. 'On the spring cultivation of autumn-sown wheat', *J. Agric. Sci.*, 1957, **27** (3), 447-457.
5. GARNER, F. H. and SANDERS, H. G. 'The effect of the "Gyrotiller" on crop yield', *J. Agric. Sci.*, 1938, **28** (3), 401-417.
6. SOANE, B. D. 'The effects of traffic and implements on soil compaction'. *J. and Proc. Inst. Agric Engrs.*, 1970, **25** (3), 115-126.
7. BROWN, N. J. 'Herbicide tillage systems in England'. *Proc. 9th Brit. Weed Control Conf.*, 1968, **3**, 1297-1301.
8. WHYBREW, J. E. 'Minimum cultivations for cereals.' *Agriculture*, 1965, **72** (**11**), 522-526.
9. PHILIP, J. R. 'The role of mathematics in soil physics'. *J. Aust. Inst. Agr. Soi.*, 1957, **23** (4), 293-301.
10. RAATS, P. A. C. 'Forces acting upon the solid phase of a porous medium'. *J. Appl. Math. and Phys.* (*ZAMP*), 1968, **19** (4), 606-613.
11. RAATS, P. A. C. and KLUTE, A. 'One dimensional, simultaneous motion of the aqueous phase and the solid phase of saturated and partially saturated porous media'. *Soil Sci.*, 1969, **107** (5), 329-332.
12. POULOVASSILIS, A. ' Steady-state potential and moisture profiles in layered porous media'. *Soil Sci.*, 1969, **107** (**1**), 47.
13. HAWKINS, J. C. and BROWN, N. J. 'Tillage and the root environment'. *Proc. Agric. Engng Symp.* (*Silsoe*), 1967, Div. 4.
14. KRAMER, P. J. 'Water stress and plant growth'. *Agron. J.*, 1963, **55**, 3-35.
15. PARR, J. F. and BERTRAND, A. R. 'Water infiltration into soils'. *Adv. Agron.*, 1960, **12**, 311-363.
16. ROSE, D. A. 'Water movement in porous materials: Part 2—The separation of the components of water movement'. *Brit. J. Appl. Phys.*, 1963, **14** (**8**), 491-496.
17. BROWN, N. J. , FOUNTAINE, E. R. and HOLDEN, M. R. 'The oxygen requirement of crop roots and soils under near field conditions'. *J. Agric. Sci.*, 1965, **64** (**2**), 195-203.
18. CURRIE, J. A. 'Gaseous diffusion in porous media'. Part 3—'Wet granular materials'. *Brit. J. Appl. Phys.*, 1961, **12** (6), 275-281.
19. CURRIE, J. A. 'The importance of aeration in providing the right conditions for plant growth'. *J. Sci. Food Agric.*, 1962, **13** (7), 380-385.
20. WIJK, VAN, W. R. 'Physics of plant environment'. North Holland Amsterdam. 1963.
21. DE VRIES, D. A. 'Het warmageleidingsvermogen van grond' (Heat conductivity of the soil). *Meded. Landbouwhogeschool Wageningen*, 1952, 52-61.
22. DUIN, VAN R. H. A. 'Over de invloed van Grondbeworking op het transport van warmte lucht en water in de grond'. (On the influence of tillage on conduction of heat, diffusion of air and infiltration of water in soil). *Versl. LandbouvkOedra*, 1956, 62.7 S'Gravenhage.
23. ABDALIA, A. M., HETTIARATCHI, D. R. P. and REECE, A. R. 'The mechanics of root growth in granular media'. *J. Agric. Engng Res.*, 1969, **14** (3), 236-248.
24. TAYLOR, H. M. and RATLIFF, L. F. 'Root elongation rate of cotton and peanuts as a function of soil strength and soil water content'. *A.S.A.E. Proc, Paper No. 68*, 1968, 668. St Joseph, Michigan 49085.
25. EAVIS, B. W. and PAYNE, D S'oil physical conditions and root growth'. *Root Growth Edt. Whittington*, 1969. Butterworth.
26. COCKROFT, B., BARLEY, K.P and GREACEN, E. L. 'The penetration of clays by fine probes and root tips'. *Aust. J. Soil Res.*, 1969, **7**, 333-348.
27. JONES, F. G. W., LARBEY, D. W. and PARROTT, D. M. 'The influence of soil structure and moisture on nematodes, especially Xiphinena Longidorus Trichodorus and Heterodera SPP. *Soil Biol. Biochem.*, 1969, **1**, 153-165. □

THE EFFECTS OF TRAFFIC AND IMPLEMENTS ON SOIL COMPACTION

by B. D. SOANE, BSc, MS, PhD*

Presented at the Annual Conference of the Institution in London on 12 May 1970.

1. Introduction

Agricultural production today is dependent on the use of an ever extending range of machinery. In the context of rising costs and shortage of labour the mechanical and economic efficiency of this machinery is generally high and it seems probable that the trend for larger, heavier and more complex equipment will continue. There is concern however, that this trend may be associated with a reduction in soil productivity. This interest is not entirely new; even before the first tractor appeared critical farmers were concerned with the subject, as shown by the writings of Scott[1] who gave a detailed description of the compaction damage from the trampling of horses in the furrow bottom. During and after the war years the subject was largely forgotten as great strides were made in the boosting of crop yields with ever more liberal application of fertilisers. During the last decade however, economic pressures have led to many changes in crop and soil management and the virtual elimination of both rotations and stock from the farming scene in many areas. These changes were contrary to the long established practices in British farming and some voices were heard to predict that no good would come from such poor respect for the soil. With the experience of the last two seasons it seems that there may now be some serious reconsideration of the situation as shown by the following quotations.

Rowsell,[2] 1967 Oxford Farming Conference.
"This system of monoculture . . . is leaving our land worse than at any other time in its history".
Rt Hon Cledwyn Hughes,[3] MP, Minister of Agriculture, 1969.

"I am concerned that we should be well informed about any effect which modern farming methods may have in the long term on the fertility and structure of the soil".

Waller,[4] Editor, Journal of the Soil Association 1969.
"As the soil structure breaks down, especially under the impact of heavy machinery, it ceases to be a suitable medium for feeding the fertiliser to the plant . . .".

It is not possible to point to any single factor as the sole cause of the deterioration in the physical fertility of our soils. Many aspects of long-term changes in crop production practices are likely to be responsible. The early fears expressed about the introduction of the tractor have been given some credence by the work of Van Ouwerkerk[5] who found that ". . . the structure of fine-textured soils is generally worse on farms with tractor traction than on farms with horse traction. This negative effect of mechanization seems to be most pronounced in years with a bad soil structure." One of the most important changes in machinery use in recent years has been the striking increase in use of heavy harvesting machinery (Fig. 1) which has altered the pattern of traffic at a time when soils particularly in the north and west of the country tend to be moist and do not support heavy loads without permanent deformation.

* Agricultural Department, Scottish Station, National Institute of Agricultural Engineering.

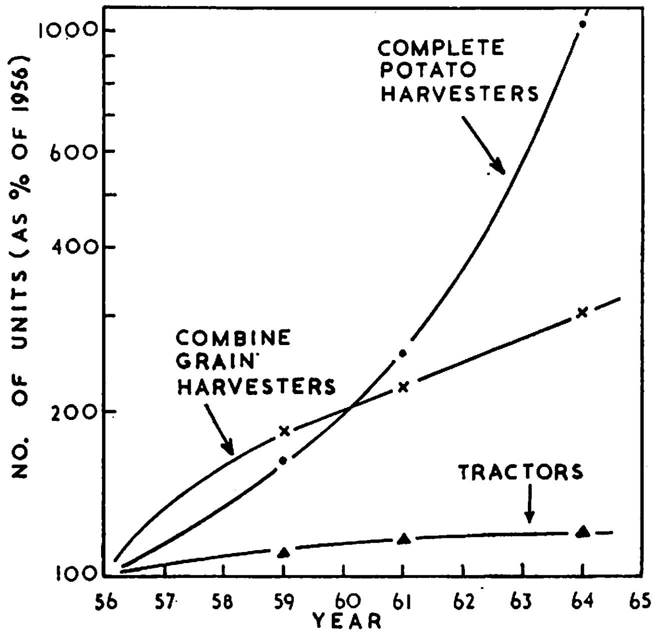


Fig. 1. Changes in the number of complete harvesters compared with that for tractors in Scotland (1956 = 100).

The reduction in the grass acreage which has occurred even on marginal land, is likely to lower the resistance of soils to the compaction effects of machinery, partly because there will be an increase of disturbance and traffic but also because any reduction of organic matter will accentuate deterioration in structure. The views of Crompton[6] on the essential role of grass in maintaining soil structure seem to have been largely forgotten in the present emphasis on cereal production.

The significance of compaction effects in terms of crop production is strongly dependent on weather conditions[7] and the current interest in the subject largely stems from the experiences of farmers during and after the 1968 season. It is therefore of interest to note the work of Håkansson[8] in which the effects of compaction are studied under different moisture regimes.
It is important to appreciate that compaction problems arise in practically every form of agricultural and horticultural undertaking, the grazing and harvesting of grass and even in forestry.[9] Until very recently research workers in this country had taken little interest in compaction; a conference[10] on compaction attended by European and American specialists in 1965 received no contribution from British workers.

2. The Problems Facing the Research Worker

Answers are needed to the following questions:

1. Does compaction occur in field soils and if so under what circumstances?
2. If it occurs, does it have deleterious effects on crop growth or crop harvesting practices?
3. Can compaction be avoided or reduced by suitable changes in design and use of machinery?
4. If compaction is unavoidable what remedial action is appropriate?

Information is required on this subject at two levels. Firstly, the physics of the machine/soil and soil/plant inter-relationships must be understood. These are very complex systems to which the present theories and techniques of soil mechanics and plant physiology can be applied to only a very limited extent. Secondly, a broad approach to the economics of machinery usage must be made in relation to short and long-term responses of the soil and crops in order to ensure that research information can be related realistically to field practices, always a difficult operation. In finding answers to the four questions just posed the research worker must first decide what soil properties he will measure. It is known that compaction

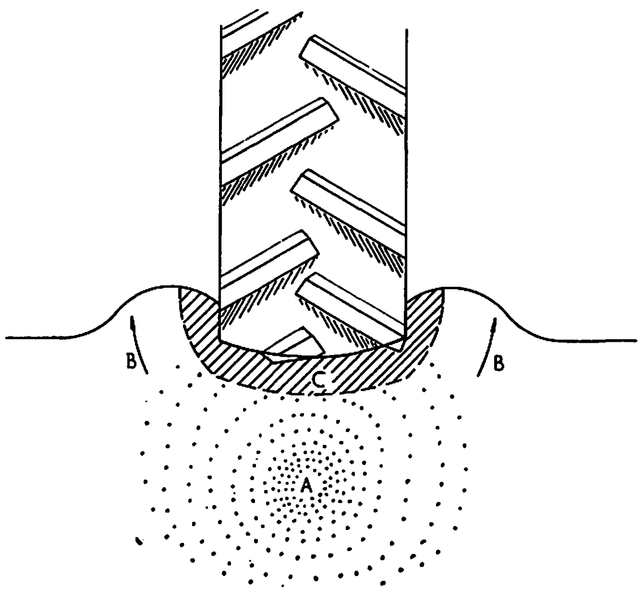


Fig. 2. Diagram showing the distribution of principal zones of soil reaction to the passage of a wheel over field soil.

will result in changes in the dry bulk density, the hydraulic conductivity, the air-filled porosity, the various strength characteristics, the thermal conductivity, the pore size distribution, the water retention characteristics and many other properties. It is necessary to consider the measured properties not only on a 'bulk' basis but also their distribution among and within the soil horizons. This is illustrated by the problems associated with high density, high strength 'clods' within an otherwise satisfactory soil. The clods may represent a significant proportion of the rooting volume and yet be virtually unavailable to the growing root.

3. The Compaction Process

3.1 Definition

Compaction is a process in which the rapid application of a load results in the increase of soil dry bulk density and an associated decrease of air-filled porosity without a change in moisture content. It must be distinguished from consolidation which is generally defined as a long-term volume change due to overburden or static loads, and from slumping which is the increase of dry bulk density due to the loss of strength and soil movement resulting from increases of moisture content. A further associated effect is non-compactive deformation which may occur locally under a loaded surface either as puddling or over a larger volume as plastic flow. All these effects contribute to important changes in soil physical properties and the passage of a wheel is accompanied by a complex association of these processes (Fig. 2).

In Zone A there is concentration of downward and shearing stresses from the applied load and compaction occurs with an intensity and distribution which is dependent on the applied pressure, the total load and the shape of the loaded area as well as the distribution of soil strength below the surface. Soil movement without appreciable compaction occurs in Zone B. This will result in the rise of the soil surface on either side of the rut. The amount of this movement will depend on both the strength and compactability of the soil. If the soil is very wet the compactability is low as the pore space is largely filled with water. In this situation the degree of compaction is slight and the plastic deformation will be large. The soil immediately under the wheel, Zone C, is subject to very intense shearing action especially when wheel-slip is high. As a result there is a considerable amount of puddling and smearing with a destruction of the natural structure. Although the depth of this zone may be small it can be of considerable importance in affecting soil properties especially when a tractor wheel is running in the bottom of a furrow. The discussion which follows is primarily concerned with the soil changes in Zone A.

3.2 Quantitative treatment of the compaction process

There appears to have been no comprehensive treatise on compaction although reviews have been prepared on certain aspects of the subject.[11, 12, 13, 14] Empirical observation had led to the implication of a number of soil and load characteristics in the compaction process (Table 1). Under field conditions virtually all of these characteristics exert influence on compaction effects. It is necessary to consider the factors both individually and in relation to each other in order to understand the process as a whole.

TABLE 1

Factors affecting the incidence of compaction

Soil characteristics	Load characteristics
Intrinsic 'strength'	Surface pressure
Moisture content	Distribution of pressure
Particle and aggregate size distribution	Impact effects
Organic matter content	Shape and size of loaded surface
	Total load
	Vibrational components
	Rate of application and duration of stress
	Presence of shear stresses

The incidence of compaction is largely affected by the relative magnitude of the soil 'strength' and the surface pressure.[9, 15] If the surface pressure is less than the soil 'strength', compaction will not occur whereas in the opposite condition displacement and compaction occur until the soil 'strength' rises to equal the applied pressure. If the applied pressure greatly exceeds the initial soil 'strength' then deep sinkage may occur accompanied by complete shear failure rather than compactive failure. However before we attempt to examine field situations it is useful to examine the influence of some of these characteristics individually.

4. Soil Characteristics

The properties of soils which influence compaction have been studied in detail in the field of civil engineering but have received little attention in agricultural soil science. A paper on 'compactability' in a text-book on the analysis of agricultural soils[16] contained no reference to compaction in the context of agriculture. Although many of the principles established in civil engineering are equally relevant in agricultural soils there are some important differences in details, particularly in relation to the degree of aggregation and the organic matter content.

4.1 Laboratory tests for soil compactability

Details of laboratory compactability tests used in civil engineering are readily available.[12, 16, 17] The standard compaction test (Proctor) employs impact loading and has achieved widespread acceptance regardless of the type of loading which is employed in the field. Workers with agricultural soils have used a variety of tests,[14, 18] in some of which dynamic loading is employed to simulate conditions in the field. There is, however, no generally accepted test for agricultural soils. Laboratory tests are useful in establishing the influence of various soil properties on compactability but generally fail to indicate the influence of varying load characteristics.

4.2 The effect of moisture content

For a given type and amount of compactive loading the degree of compaction achieved is strongly dependent on the

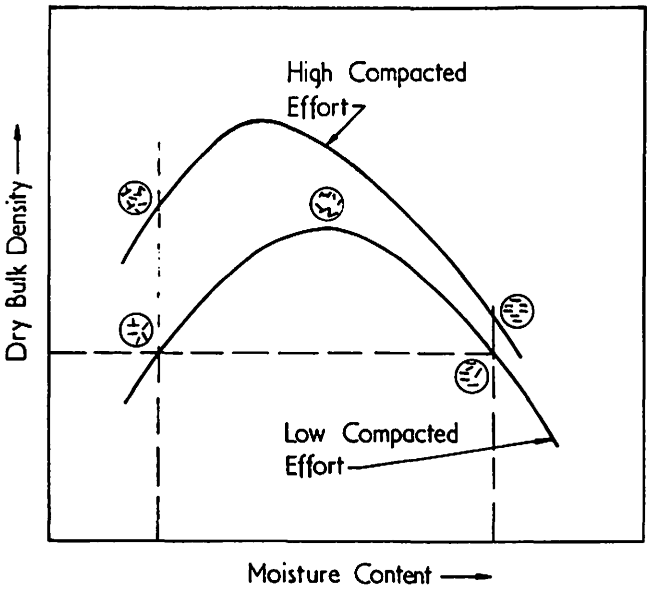


Fig. 3. Relation between bulk density and moisture content for high and low compacted effort (after Lambe[26]).

moisture content (Fig. 3). This effect is associated with the action of water as a lubricant, permitting particles to take up positions of closer packing. Maximum dry bulk density is obtained at a certain optimum moisture content which is related to the size distribution and shape of the soil particles. As the compactive effort increases the maximum bulk density increases but the optimum moisture content decreases. In Fig. 3 the microscopic arrangement of particles is indicated diagrammatically within the circles, the compacted soil being in a generally disordered state at low moisture contents whilst at high moisture contents the particles tend to be aligned in an ordered laminar form.

The line joining the peaks of such curves has a slope which is a characteristic of the type of compaction which is being applied. For example Fig. 4 shows the lines obtained for static pressure, dynamic pressure, a sheepsfoot roller and a rubber-tyred roller.[13] The prediction of compactive response in the field from a simple laboratory test can be only approximate. The optimum moisture value is related to the basic mechanical and moisture characteristics of the soil. For the standard (Proctor) compaction test the optimum moisture content generally lies at a value slightly lower than the plastic limit and about half-way between the moisture contents at one-third and 15 bar suction[18] although Mazurak and Chesnin[19] reported an optimum moisture content at one-third bar suction. In general it has been found that in this climate there is little hope of avoiding compaction by waiting for more favourable moisture conditions since many operations have to take place when soils are readily compacted.

4.3 Particle and aggregate size distribution

Particle and aggregate size distribution have a marked influence on compactability of mineral soils.[9] Spherical particles of density 2·6 g/cm³ when arranged in closest packing (tetrahedral) would give a dry bulk density of 1·9 g/cm³. However a well-graded gravel may give maximum dry bulk density and optimum moisture values (Proctor) of 2·2 g/cm³ and 4 per cent w/w respectively. The corresponding values for a heavy clay might be 1·4 g/cm³ and 28 per cent w/w. Agricultural topsoils generally show pronounced aggregation and the size of the aggregates has been found to affect the compactability of soils.[20, 21]

4.4 Organic matter

Soil compactability is also influenced by its organic matter content. The greater the organic matter content the lower the maximum dry bulk density and the higher the optimum

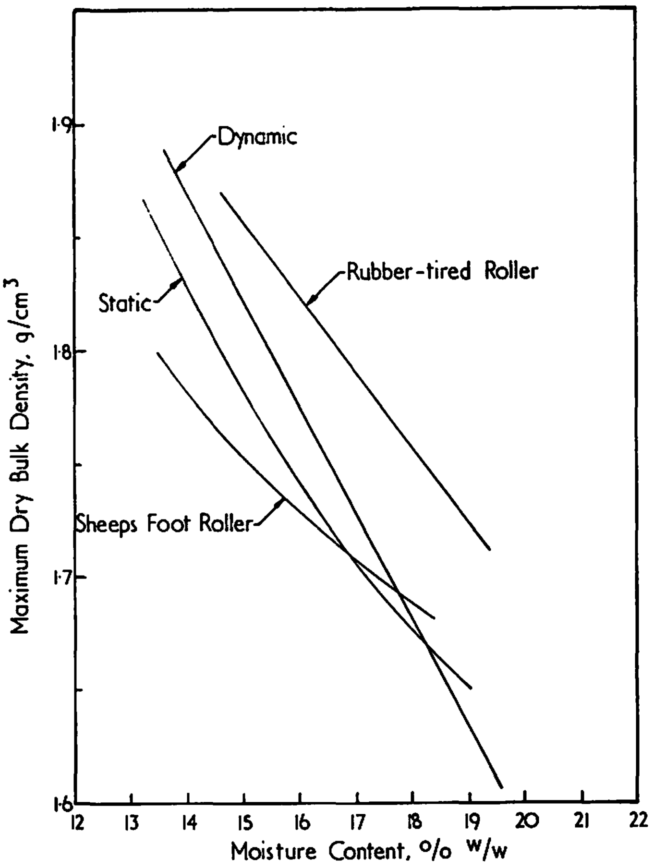


Fig. 4. The relation between maximum dry bulk density and moisture content for different methods of compaction (after Foster[13]).

moisture content. This suggests that any deterioration in the level of organic matter content of field soils may be an important influence on the response of soils to applied loads. There are some striking examples in the literature.[18, 22, 23] For instance Bruce[18] used a compactability test to measure the maximum bulk density for a soil after continuous corn, in a mixed rotation with manure and in a pasture condition. The respective bulk densities were 1·75, 1·61 and 1·53 g/cm³ while the corresponding optimum moisture contents were 15·5, 18·0 and 21·0 per cent w/w. Swanson[22] investigated the effect of additions of farm-yard manure on the reduction of macropores under wheel tracks for heavy and light tractors. For a light tractor (1 300 kg) there was a marked resistance to deformation in the presence of farm-yard manure but with a heavy tractor (1 830 kg) the extra organic matter made no difference to the change in pore-size distribution. Free, Lamb and Carleton[23] showed that a reduction of organic matter content from 4·1 to 2·5 per cent in a silt loam resulted in the maximum dry bulk density increasing from 1·4 to 1·61 g/cm³ and the optimum moisture content decreasing from 26 to 22 per cent. The maintenance of adequate levels of organic matter in arable soils is therefore likely to reduce the intensity of compaction under a given load.

5. Load Characteristics

As indicated in Table 1, the precise definition of the load characteristics is difficult even in simplified laboratory tests for compactability and almost impossible for real situations in the field, yet we know that load characteristics are likely to have an important influence on compaction (Fig. 4). A brief consideration will be given to some of the factors likely to be of importance.

5.1 Average surface pressure under wheels and tracks

It is clearly important that we should know the surface pressure exerted by tractors and other machinery although

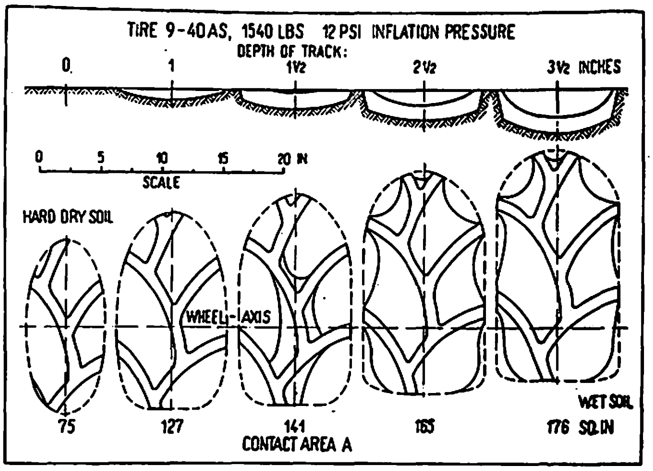


Fig. 5. The variation of contact area with sinkage (after Söhne [25]).

this is only one of the factors which are required to define the load characteristics. In its simplest form the surface pressure is obtained by dividing the load by the contact area. However when this principle is applied to practical situations a number of difficulties arise in the estimation of both factors. Some of the problems of estimating surface pressures under wheels and tracks have been reviewed elsewhere.[11, 24] The contact area of a tyre depends on the degree of sinkage, the inflation pressure and the type and dimensions of the tyre. With lugged tyres it is necessary to distinguish between the contact area beneath the lugs alone and the normal contact area of the lugs and underside of the tyre.[25] Both properties depend on sinkage (Fig. 5).

Surface pressure for a given load can be decreased by increasing the diameter or width of the tyre but there are limits set by cost, manoeuvrability and the use of tractor wheels in plough furrows. When running on soil of low strength, tyres inflated to recommended pressures for road work behave in some degree as if they were rigid and the contact area can be increased by reducing inflation pressures for field work, provided that care is taken to avoid tyre damage in subsequent travel on roads.

The contact area below tracks is not so variable as that for wheels and the product of the bearing length and width of the track is usually a satisfactory estimate of contact area except on uneven soils of high strength. In this case effective contact may not be maintained throughout the length of the track. The surface pressure below agricultural wheels is so variable that information tends to be fragmentary. For the situation shown in Fig. 5 the average surface pressure over the nominal contact area varied from 1·44 kg/cm² (20·6 lb/in²) for a firm surface to 0·61 kg/cm² (8·7 lb/in²) for a soft surface. Most agricultural tracked vehicles have average surface pressures within the range 0·28–0·47 kg/cm² (4–7 lb/in²) but certain vehicles designed for travel over exceptionally soft ground may have values as low as 0·07 kg/cm² (1 lb/in²).

5.2 Distribution of surface pressure over contact area

Theoretical assessment of compaction from a knowledge of average surface pressure is unlikely to be successful since the distribution of pressure is often very uneven especially when vehicles are in motion. The maximum pressure in the centre of a tyre on soft soil is generally considered to be about 1·2–2·0 times the average pressure. Pressure distribution under tracks may also be far from uniform due to increased sinkage at the rear of the track. Dynamic weight transfer will also affect the distribution of pressures under wheels and tracks. Finally, changes in transverse inclination will affect the load distribution. A tractor wheel running in a 25 cm furrow will bear approximately 20 per cent greater load than when working on level ground.

There is as yet very little information on the actual surface pressures exerted by wheels and tracks under field conditions and even less on the prediction of the resulting compaction effects for a range of soil conditions.

5.3 Other load characteristics

The other load characteristics listed in Table 1 are likely to contribute to compaction effects although detailed information is not available. Cumulatively they account for the degree to which the actual compaction differs from that predicted from the surface pressure effect alone. The size and shape of the loaded surface area are clearly important since the significance of these properties has been established in pressure/sinkage studies. The shape component is usually indicated by the inclusion of the minor axis of the loaded surface area in equations relating pressure and sinkage. In view of the increasing weight of machinery it is important to know whether it is possible to avoid undue compaction by increasing the loaded surface proportionally, thus maintaining a constant surface pressure. Söhne[25] has shown that under such circumstances increasing load was accompanied by increasing depth of penetration of compaction stresses. The use of a constant standard for surface pressure as the size of machinery increases will not necessarily be sufficient safeguard against further compaction effects.

The movement of tractors and machinery over uneven surfaces will result in a succession of impacts in which the loading is momentarily in excess of the normal pressure on level ground. This could be important since impact forces are known to have a particularly effective compacting action.[11] Vibration, particularly when transmitted through a rigid track, will further add to the loading effect. Cooper and Reaves[27] found that vertical stresses under a track reached peak values of 0·7 kg/cm² (10 lb/in²) although the average surface pressure was about 0·35 kg/cm² (5 lb/in²). The peaks were attributed to vibration and impact effects.

The presence of shearing stresses also augments the action of normal stresses and causes increased compaction.[11] This is likely to be of considerable importance where high traction is obtained from wheels through lateral shearing. Shearing action is also present as the soil wedge under the loaded surface advances vertically downwards. A concentration of shearing stress at some distance below the bearing surface is said to account for the higher bulk densities found in this region.[11] As a result of the numerous factors involved, the quantitative expression of loading characteristic under field conditions cannot yet be achieved and this acts as a restriction to the prediction of compactive effects.

6. The Measurement of Compaction in the Field

Compaction studies may be divided broadly into those in which measurements are made whilst the process is in progress and those in which changes are obtained from readings 'before and after'. In the former group are the use of pulsed X-rays and several photographic techniques. These have revealed the complex circular movements which occur in the soil beneath a wheel in the plane parallel to the direction of travel. The distribution of stresses may also be measured with stress transducers but there are many problems in obtaining satisfactory results as a result of the disturbance caused by the presence of the transducer in the soil.

Most field studies however have been confined to the measurement of the change of some selected soil properties and those which have been used include dry bulk density, air-filled porosity, hydraulic conductivity and soil strength. Microscopic examination of pore size distribution has also been found useful. The selection of a property depends largely on the scope of the investigation and resources available. For field investigations the measurement of soil 'strength' with a penetrometer is quick and cheap but gives results dependent on moisture content, the type of equipment and its mode of use. The measurement of changes in dry bulk density or air-filled porosity however should be independent of the method used.

6.1 Penetrometer methods

Penetrometers of various types have long been used in compaction studies, the farmer's walking stick being quite capable of demonstrating qualitatively the presence of bands of compacted soil beneath wheel tracks. An early research use of the method was reported by Davies[28] in 1933. The effects of rolling, the passage of tractor wheels and the imprint of horses hooves on soil strength were measured with a simple type of recording penetrometer. Since that time numerous types of penetrometer have been used. The most widely adopted for field tests is that used in the Cone Index test in which a 30° cone of 3·23 cm² (0·5 in²) maximum cross section is driven through the soil at a rate of approximately 1·83 m/min (72 in/min). Cone Index values may vary from around 1·4 kg/cm² (20 lb/in²) for low strength soil to above 7·0 kg/cm² (100 lb/in²) for high strength soil. For empirical tests of this type it is imperative that the equipment and mode of use should remain constant but for specialised research studies numerous other types of penetrometer have been developed to suit particular circumstances. For example a 5°, 3 mm diameter probe has been used for studies on root penetration.[29]

6.2 Methods of measuring dry bulk density

The use of core sampling for the study of changes in dry bulk density has presented several difficulties.[30] The method is tedious and is not suited to the detection of the very abrupt changes of bulk density which may occur in cultivated soils. Gamma-ray transmission using twin probes has been found to have several advantages in the study of compaction in view of the high degree of geometric resolution which may be obtained. The probes may be used in the vertical mode[32] or for two dimensional scanning.[31, 32, 33] The former system causes little disturbance and is suitable for replicated field experiments and advisory work (Fig. 6). The latter system provides very detailed information on the spatial distribution of compactive changes (Fig. 7). Special control equipment has been constructed at NIAE Scottish Station which permits density measurements to be made on a 1 x 1 cm grid over a cross section of 140 cm x 40 cm. Transmission data and the co-ordinates are recorded automatically at each position on magnetic tape. The data is then converted to paper tape and values for the moisture content data are added after independent measurements. The combined tape is then run on a computer and dry bulk density values are printed out on rectangular co-ordinates. The contours of equal density, which we have termed 'isodens', may be drawn in by eye (Fig. 9*a*) or alternatively may be automatically drawn by the computer with a trend surface analysis technique (Fig. 9*b*). In this way it is possible to use the results either to explore the detailed patterns of bulk density or the overall distributional trends. Detailed studies have shown that the calibration between transmitted gamma-ray count rate and bulk density is linear over the range of interest and is independent of soil type or moisture content at the level of prediction which is required for compaction studies.

Comparisons between core sampling and gamma-ray methods for measuring dry bulk density have shown that the same number of readings can be obtained by the latter method in approximately one-sixth to one-half of the time required for core sampling.

7. The Incidence of Soil Compaction in the Field

7.1 Compaction from the passage of wheels and tracks

In this section results obtained at the NIAE Scottish Station will be used to demonstrate the occurrence of compaction in a number of field operations. The data are grouped according to the type of operation.

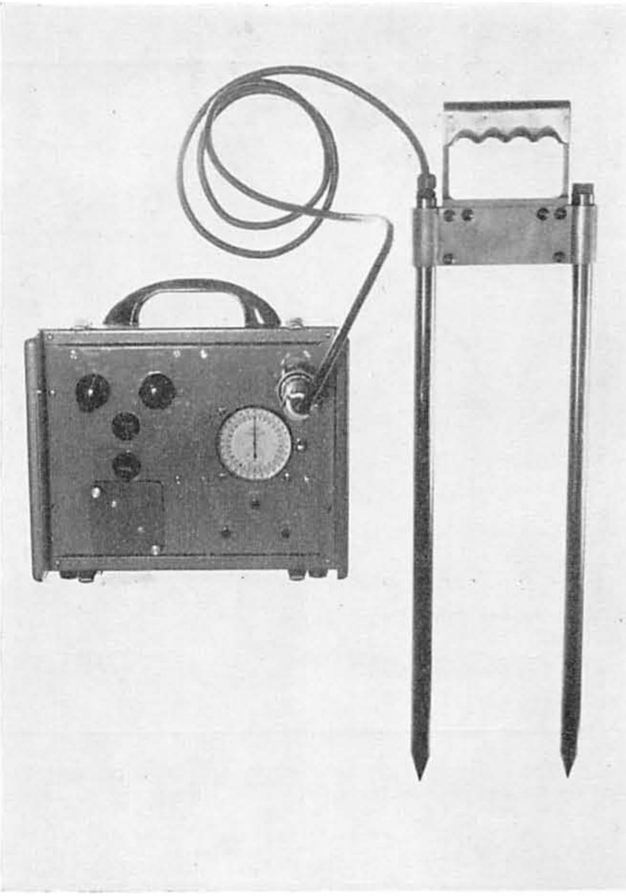


Fig. 6. Hand-held gamma-ray transmission equipment developed at NIAE Scottish Station.

Fig. 7. Gamma-ray transmission equipment developed at NIAE Scottish Station for automatic two-dimensional scanning of field soils.

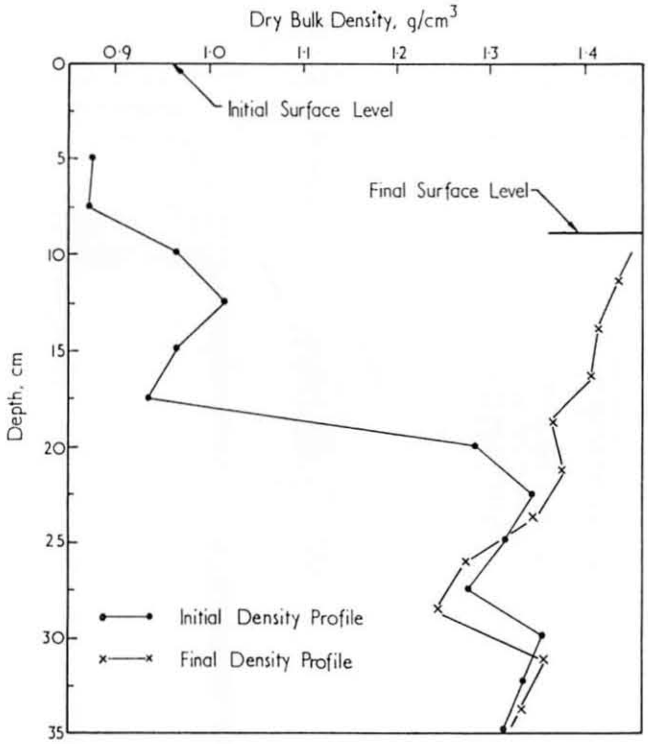


Fig. 8. The variation of dry bulk density with depth before and after the passage of a tractor wheel.

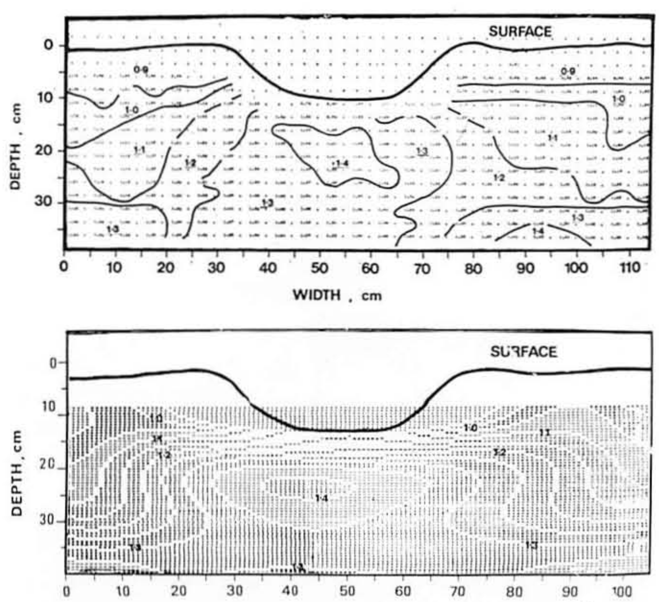


Fig. 9. The distribution of dry bulk density after passage of tractor wheel with isodens inserted (*a*) by eye and (*b*) by trend surface analysis.

7.1.1 *Seedbed operations*

In the relatively soft soil conditions normally occurring during seedbed operations tractor wheel sinkage is considerable yet the effects are often not appreciated because the passage of a following harrow or drill may smooth out the surface ruts leaving no visual record of the passage of the wheels. The residual compaction effect however may be considerable. Fig. 8 shows the variation of density with depth before and after the passage of a tractor wheel on loose soil. The readings were taken in the midline of the wheel track. The compaction effect extended to a depth of 20 cm below the depth of the uncompacted surface. When the same effect was measured in cross section using two dimensional scanning at a different site the lateral distribution of the compaction effect was obtained (Fig. 9*a* and *b*).

Fig. 10. Example of very poor emergence of barley partially attributable to soil damage under wheel tracks.

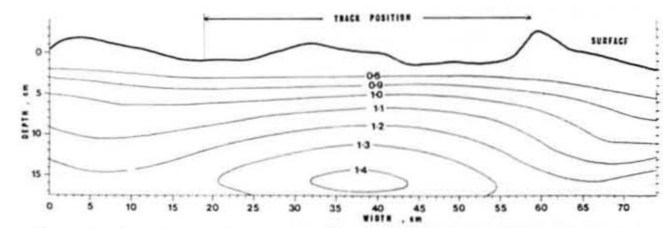


Fig. 11. The effect of passage of crawler tractor with mounted spring-tine harrow on distribution of dry bulk density (g/cm³).

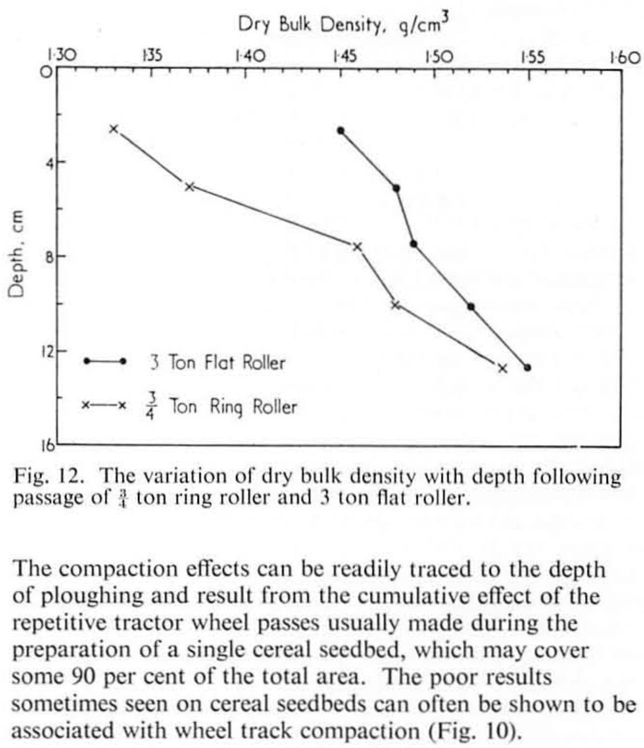


Fig. 12. The variation of dry bulk density with depth following passage of ¾ ton ring roller and 3 ton flat roller.

The compaction effects can be readily traced to the depth of ploughing and result from the cumulative effect of the repetitive tractor wheel passes usually made during the preparation of a single cereal seedbed, which may cover some 90 per cent of the total area. The poor results sometimes seen on cereal seedbeds can often be shown to be associated with wheel track compaction (Fig. 10).

In some areas the compaction dangers of seedbed traffic are fully appreciated and farmers attempt to reduce surface pressures by the use of cage wheels or crawler tractors. While this action will reduce the intensity of compaction it will not eliminate it. After a harrowing operation with a crawler tractor evidence was found of compaction remaining below the depth of harrowing (Fig. 11). Compaction effects under tracks have also been reported by Steinbrenner.[34]

Deliberate surface compaction of seedbeds is widely practised in drier areas in order to improve the soil-seed contact on soils which tend to be too dry for rapid germination. On stoney soils, surface rolling after drilling is sometimes practised to level the surface and reduce damage to combines. Gamma-ray studies (Fig. 12) have shown how the pattern of bulk density is affected by the weight of the roller used for this purpose.

7.1.2 *Spraying operations*

In many crops frequent spraying for disease or pest control introduces repetitive loading of soils which can cause serious restriction to soil productivity, particularly for fruit crops in which the passage of wheels may have to take place above the rooting zone of the crop. Fig. 13 illustrates an apparent restriction to the emergence of suckers in a field of raspberries for the propagation of planting material rather than for fruit. A zone on either side of the original planting row was observed to be completely free of suckers although, at greater distances from the planting row, they were emerging normally. Tests with the gamma-ray density equipment (Fig. 14) established that there was a distinct difference in the bulk density of the soil in the sucker free zone from that where the suckers were emerging freely. In further studies with raspberries repetitive passage of rotary cultivating equipment (Fig. 15*a*) was shown to produce marked increases in bulk density under the wheel tracks which are slightly wider than the width of cultivation. When the results are transformed to the air-filled porosity basis the effect is equally striking (Fig. 15*b*).

Spraying operations in potato crops may cause considerable compaction in the furrows in which the wheels run (Fig. 16). This causes an increase of bulk density in the lower sides of the ridges as well as below the furrow. Under certain harvesting conditions this could result in increased draught and incidence of clods.

7.1.3 *Harvesting operations*

In some areas harvest traffic occurs at a time when soils are at a comparatively low moisture content and high strength but this is far from certain in this country and is unusual in the wetter regions of the north and west. In these parts the high soil moisture and limited traction can cause damage to soils from harvest traffic. Fig. 17 shows the changes in bulk density which occurred under the wheel tracks of normal cereal harvest traffic (tractors and combines) for average soil conditions in this area. Where deep ploughing had occurred 11 months previously, harvest traffic was found to increase the bulk density at 5 cm depth from about 1·25 to 1·40 g/cm³ and the effect extended to about 15 cm. However where no ploughing had occurred in the previous autumn and the crop had been planted by direct drilling in the spring, there had been no loosening of the compaction occurring in the previous cereal harvest. As a result the pattern of bulk density in the untracked soil showed a close similarity to that in the wheel tracks of the ploughed treatment. An increase of about 0·05 g/cm³ was also found for the unploughed plots in the wheel tracks but this extended to a depth of less than 10 cm. These results suggest that the traffic at cereal harvest is likely to be particularly important in modifying the soil conditions for the following crop, especially in areas in which soils are frequently in a readily compactable state at that time.

7.2 Compaction during primary tillage

All tillage operations are accompanied by certain compaction effects which in some measure detract from the benefits of the operation. In the case of mouldboard ploughing, compaction occurs in three ways. Firstly the land-side tractor wheels increase the bulk density of the unploughed soil, increasing the draught and the occurrence of clods in the ploughed soil. Secondly, compaction from the wheel running in the furrow bottom is particularly damaging owing to the extra load on these wheels. Thirdly, the passage of the plough itself, both on the furrow bottom and the land-side of the furrow has a compactive and smearing effect. Repetitive ploughing at the same depths may give rise to an intensely compacted layer or plough pan. Dutch results suggest that compaction below the furrow bottom can be detected to 20–25 cm below the depth of ploughing. In some areas there is general acceptance of the advantages of using crawler tractors for ploughing operations but this practice is still limited to a small proportion of the arable acreage in this country. An indication of the patterns of dry bulk density occurring during ploughing operations is given in Fig. 18. The sharp rise in bulk density below the depth of ploughing is clearly shown and it is of interest that this effect continued under the unploughed three-year grass ley and was presumably a residual effect from previous ploughing operations. There is an indication of compaction on the land-side of the furrow but it has not been established whether this effect is due to the passage of the plough or of the land wheel of the tractor on turning an earlier furrow.

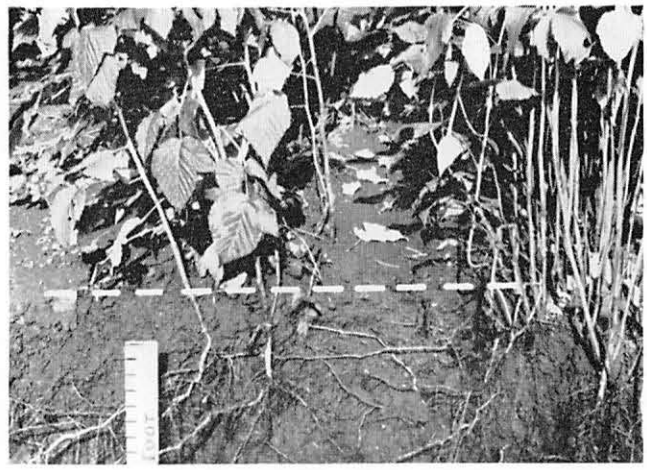


Fig. 13. Apparent restriction of raspberry sucker emergence along a wheel track.

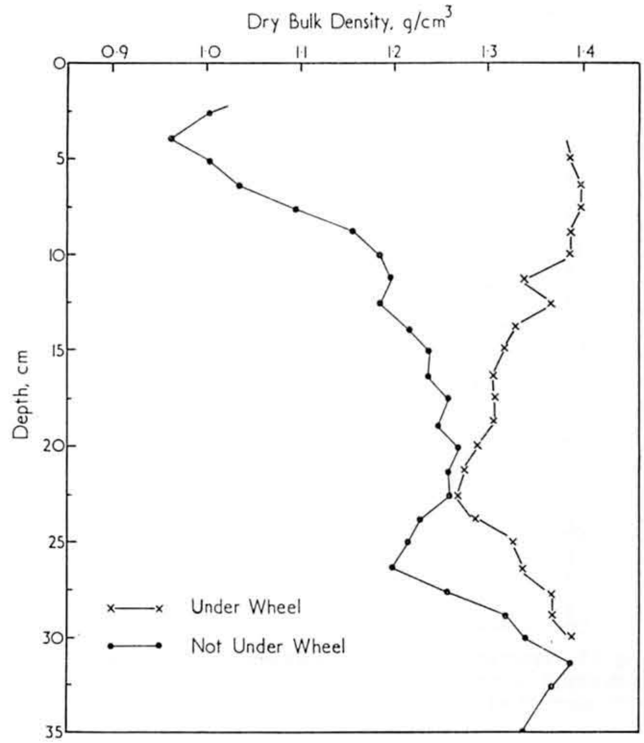


Fig. 14. Variation of dry bulk density with depth in relation to wheel track position under raspberries.

7.3 The depth of compaction effects

The seriousness of a compactive response to the passage of wheels and implements depends to a marked extent on the depth to which the effect extends. Under certain conditions the depth of influence may be considerable.

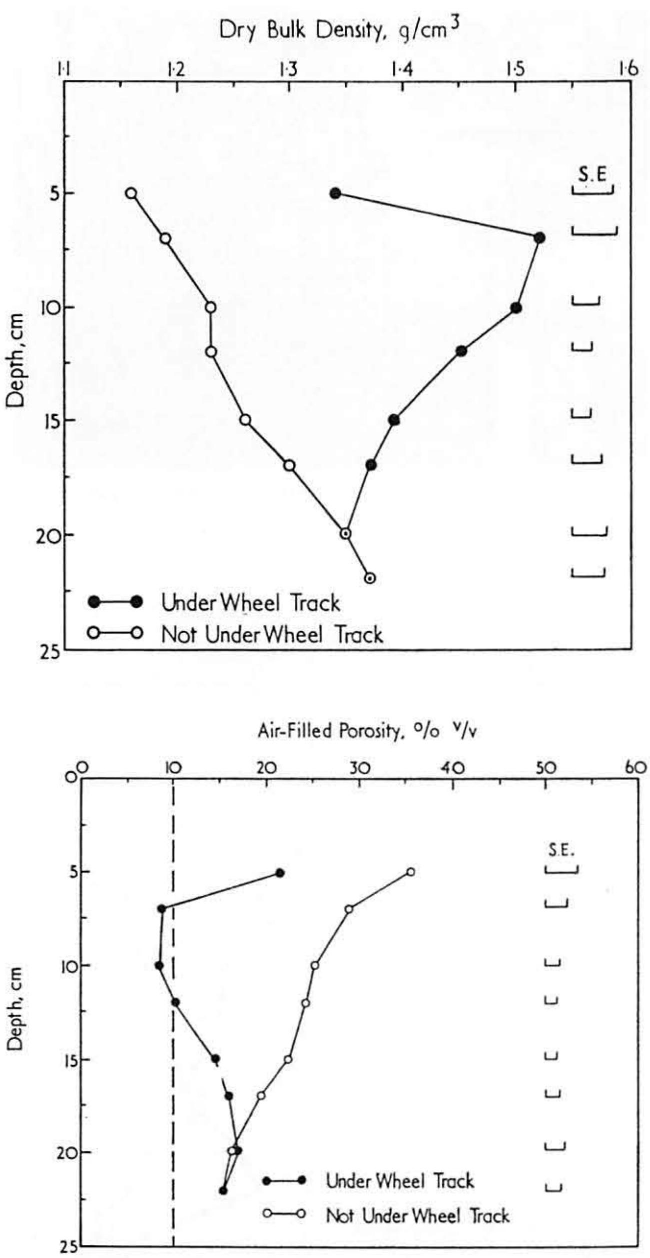


Fig. 15. Variation of (*a*) bulk density and (*b*) air-filled porosity with depth in relation to wheel track position in raspberry cultivation experiment.

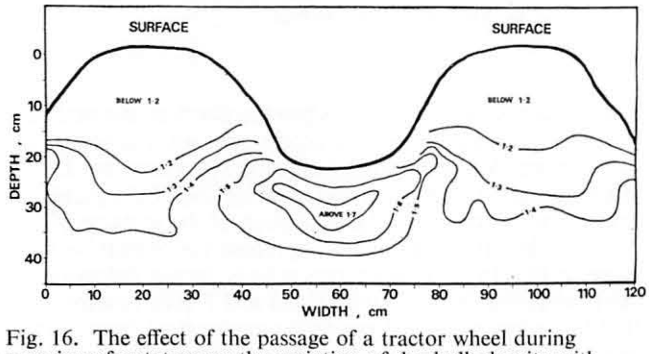


Fig. 16. The effect of the passage of a tractor wheel during spraying of potatoes on the variation of dry bulk density with depth.

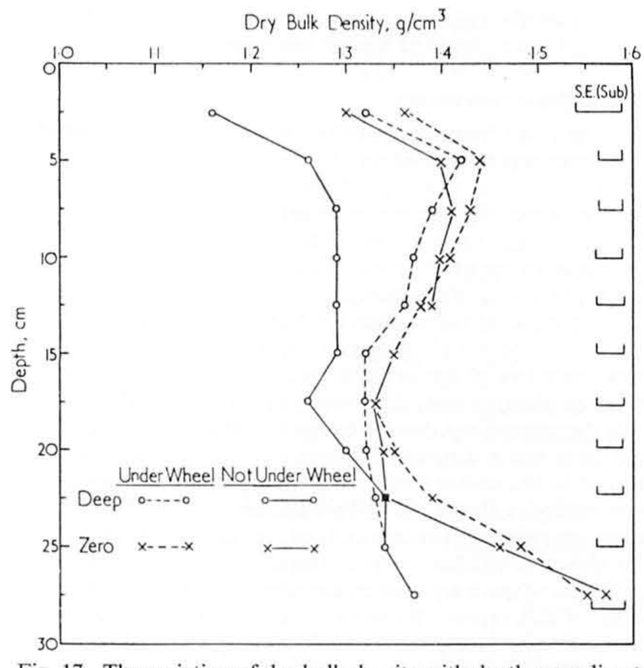


Fig. 17. The variation of dry bulk density with depth according to the passage of wheels of cereal harvesting machinery over plots previously deep and zero-ploughed.

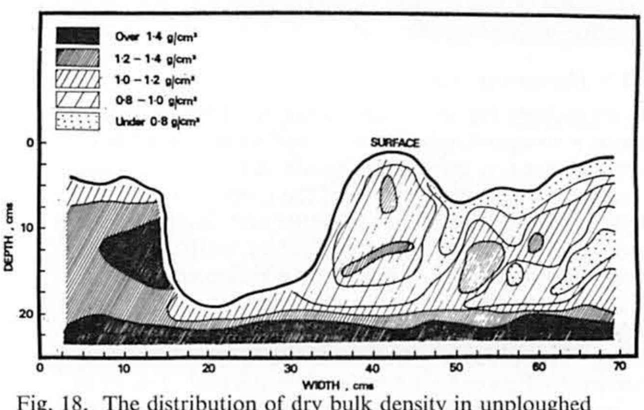


Fig. 18. The distribution of dry bulk density in unploughed (left) and ploughed (right) soil under three-year ley.

Stresses of 0·35 kg/cm² (5 lb/in²) have been recorded 38 cm below the surface during the passage of a track[27] and there are numerous reports of compaction detected at up to 25 cm depth. The depth to which compaction extends depends on the soil strength, being much greater on weak soils than on firm soils. Most arable soils show a pronounced increase of strength at the depth of ploughing, due partly to the compaction effects already considered. In these circumstances it is unlikely that compactive loading on the surface will cause any further increase of bulk density below the depth of ploughing although very marked compaction may occur down to that depth (Fig. 8).

8. The Significance of Compaction in Crop Production

The subject of compaction must remain academic unless it can be shown that the resulting changes in soil properties are of economic significance in crop production. The subject must be examined in the widest terms with full recognition of the influence of different soils and weather conditions. The effects of compaction may be divided into those in which a direct response in root growth or activity can be detected and those which exert an indirect action, to which responses may be delayed or be dependent on subsequent weather conditions. These include crop yield responses, changes to the hydrological balance of the profile and the incidence of clods at potato harvest.

Changes in bulk density serve as a useful indication of compactive change and since the classical work of Veihmeyer and Hendrickson,[36] numerous workers have reported 'critical' values for bulk density. Examination of the literature however shows that widely differing results are associated with different crops, soils and moisture conditions.

As a result the use of bulk density as a criterion of plant response requires qualification in terms of individual soil characteristics. Plant physiologists have frequently used and compared mechanical strength and aeration as criteria of the root environment and it is useful to consider the significance of these properties in compacted soils.

8.1 Compaction and mechanical impedance

Hawkins[37] stated that the increase of density from the passage of tractors "... has reached a level far below what is accepted as too dense for plant roots to penetrate ..." This may represent an over-optimistic viewpoint.

Rosenberg[38] in a comprehensive review stated that there was considerable evidence for mechanical impedance on compacted soils and the work of De Roo[39] and Jamison *et al*[40] on the root restriction of field crops confirm this for some American soils.

Mechanical impedance, as measured with penetrometers of various designs, has been found to be a useful indication of root penetration and extensive research has been undertaken on the interactions between soil strength, root growth and moisture status. It is recognised that many aspects of root growth behaviour do not conform to the action of a blunt penetrometer. However the use of a sharp probe has been shown[29] to serve as a useful indication of the soil resistance to cylindrical expansion which is believed to be an essential aspect of root penetration. A restriction in root length does not necessarily result in a decrease of dry matter production in leaves and stems of cereals[35] and there is little information on the relation between root growth and yield for crops under field conditions.

8.2 Compaction and aeration status

Severe compaction can be shown to reduce the air-filled porosity value of field soils to below 10 per cent and as a result of excess precipitation and restricted permeability it may drop to below 5 per cent. There are numerous accounts of observations of 'critical' air-filled porosity values ranging from around 5 to 12 per cent for adequate growth and yield of field crops but proof is often lacking that oxygen deficiency was necessarily the cause of growth restriction since air-filled porosity values are correlated with both bulk density and soil strength in compacted soils. Greenwood[41] shows theoretically that air-filled porosity values less than about 8 per cent are likely to result in anaerobic zones in the soil but states that "there will be no anaerobic zones and no restriction of growth unless the soil is almost completely waterlogged. As this condition seldom occurs in U.K. agricultural soils, root and top growth will rarely be impeded by lack of oxygen." It would seem that where soils are compacted, restricted aeration (or accumulation of toxic materials) will occur for longer periods and over a wider range of water contents than for uncompacted soils but the quantitative proof of this under field conditions has yet to be obtained.

8.3 The effect of compaction on yield of farm crops

Owing to the many factors which influence yield it is rarely possible to establish any direct causal relationship between changes introduced by specific compactive treatment and yield. Under certain conditions, particularly in drier climates, yields have been shown to increase after compaction[28, 42] and a parabolic response of yield on bulk density has been widely reported in laboratory studies. However in this area soils are generally above the "optimum" bulk density. There is considerable evidence indicating that important yield depressions in the field can occur following compaction,[19, 43, 44, 45] even for only slight changes in bulk density. For instance Adams *et al*[43] found that increasing the bulk density of surface soil from 1·07 to 1·19 g/cm^3 resulted in reductions in yield of potatoes and wheat of 54 per cent and 13 per cent respectively. In some field experiments the applied compaction treatments may appear to be too severe or artificial to be relevant and more realistic results might be obtained by comparing current machinery usage with treatments in which surface loading is reduced or even restricted to limited areas. The presence of compacted regions causing a limitation to root volume may affect the nutrient balance of the crop and any field studies which involve compaction or minimum tillage treatments should have at least nitrogen fertiliser applications as supplementary treatments.

8.4 The effect of compaction on soil water status

The influence of changes in soil physical properties are less apparent under low moisture conditions than during periods when precipitation exceeds evapotranspiration. One reason for this is that very marked reductions in hydraulic conductivity result from an increase of dry bulk density, for example an increase of bulk density from 1·2 to 1·4 g/cm^3 has been found to cause a ten-fold decrease in hydraulic conductivity.[46] The presence of a permanent compacted layer such as a plough pan is therefore likely to act as a severe restriction to the drainage of excess water. Pizer,[47] Hawkins and Brown,[48] in this country and Wind[49] and Wesseling[50] in Holland have drawn attention to the practical implications of a plough pan on soil hydrology. The effect will be felt in spring by a reduction in drying rate and delay in planting as well as the development of poor conditions of aeration after heavy rain during the growing season. On soils of very low water retention it is possible that the restriction to permeability at a plough pan could be an advantage in view of the benefits claimed from artificial barriers in those circumstances.[51]

8.5 Compaction and the clod problem

An additional indirect effect of compaction is an increase in the numbers of high strength clods following subsequent tillage.[53] This may detract from the efficiency of mechanised potato harvesting techniques and possibly necessitate the use of special harvesting equipment which would not otherwise be required. The strength of these clods may be such that sufficient preliminary agitation to eliminate them during lifting cannot be given without damaging the tubers. The use of special tillage techniques prior to planting potatoes and a reduction of post-planting traffic in the crop result in a considerable decrease in clod numbers at harvest. Clods can also represent a problem in the preparation of fine seedbeds, particularly when a mild winter follows the ploughing of a heavily compacted soil. The high strength and low air-filled porosity conditions in clods result in local areas which are virtually unavailable for root growth and yields have been shown to have been depressed on cloddy soils.

9. Tillage in Relation to the Occurrence of Compaction

9.1 Tillage as a cure for compaction

It is necessary to examine whether tillage is an adequate technique for restoring the soil to a suitable condition for crop production and whether a reduction in the incidence of compaction could permit an associated reduction in tillage and hence decreased production costs.

Tillage of compacted soils is less efficient than the same operation on uncompacted soil, the power requirement is higher, the comminution is less and the density and strength of the secondary aggregates (clods) produced are higher.[52, 53] Soil compacted from severe harvest traffic will almost certainly need to be ploughed or cultivated below the depth of compaction if a satisfactory seedbed is to be obtained whereas only very shallow cultivation to produce a sowing tilth might otherwise have been adequate. Extra tillage, therefore, has to be undertaken to undo the damage from compaction. Primary cultivation alone on compacted soils is frequently unable to give an adequate seedbed owing to the persistence of high density clods whose presence may be traced back directly to the regions of high density created under wheel tracks. The current widespread use of rotary cultivation prior to potato planting seems to be an expense which could probably be wholly charged to the compaction account, since, if soils had been left in an uncompacted state after the previous crop, it is unlikely that this rotary cultivation would be required. Subsoiling is another expensive tillage operation which may be required to improve compacted soil below the depth of ploughing. Hoskyns[54] in 1857 considered that "The mere invention of the subsoiler is a standing commentary on the mischief done by the plough" and we have no cause to think his views less true now than then. Yield responses up to 19 cwt/ac barley have been attributed to subsoiling[7] and although responses are not always obtained, it seems that the physical conditions in the subsoil are of more importance than generally recognised.

9.2 Minimum tillage for cereals in relation to compaction

The current interest in minimum tillage as a means of reducing costs has to be related to the incidence of compaction. In some instances the substitution of shallow cultivation in place of ploughing has given a two-thirds reduction in man-tractor hours per acre without any apparent reduction in yield of wheat.[55] Elsewhere however, cereal yields have been reduced in the absence of ploughing and there is evidence that this may be due to adverse soil physical conditions although other factors are involved also.

Bulk density readings were taken in June in a replicated experiment in which deep (30 cm), and shallow (15 cm) mouldboard ploughing were compared with chisel and no ploughing, the ploughing having been undertaken in November and the area subsequently drilled to barley (Fig. 19). The effects persisted throughout the growth of the crop and readings of air-filled porosity obtained following a wet period (Fig. 20) suggest that physical conditions were less favourable in the absence of ploughing. This was subsequently supported by yield results.

9.3 The duration of compaction effects

There is evidence for the persistence of compaction effects in soils in spite of tillage and frost action. Swedish workers report yield reductions of 5–10 per cent following compaction during the harvest of the previous crop. This effect may be associated with the results of Vomocil and Flocker[53] who showed that field compaction resulted in pronounced changes in structure and strength of aggregates in the following years. The effect was discernible even after comminution of aggregates to a diameter of only 1 mm. The unchanged persistence of compaction in subsoils, which are not subject to disturbance by tillage or frost action has been reported by Van Ouwerkerk.[56] Elsewhere a reduction of bulk density of severely compacted surface soils over a three year period was attributed to frost action.[45]

10. Discussion

Having presented some evidence for the occurrence of compaction in field soils and its probable deleterious effects on crop production it is necessary to consider briefly whether the problem can be reduced by changes in machinery design or soil management. There is clearly no single solution to the problem. Firstly a searching look must be taken at the running gear of tractors and harvesting equipment. The Swedes have made some remarkable achievements in the field of sugar beet harvester design in which particular attention is given to the performance of wheel systems under the worst soil conditions. The use of dual and cage wheels on tractors could be greatly extended. The compaction effect under tracks must also be examined since one cannot dismiss this as negligible.

Information is needed on the compactability of soils and the extent to which this is influenced by the organic matter content, the previous soil treatment and the nature of the compacting load. The development of improved tillage machinery to reduce the draught of implements would be a notable advance since at the moment the enormous traction requirements of ploughing operations necessitate the use of

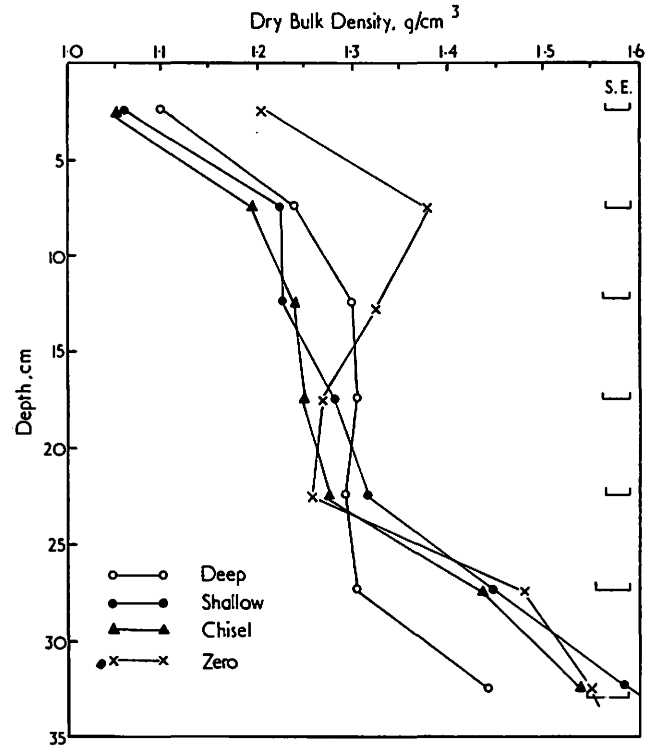


Fig. 19. The variation of dry bulk density with depth at the emergence of spring barley according to the type of ploughing used in the autumn.

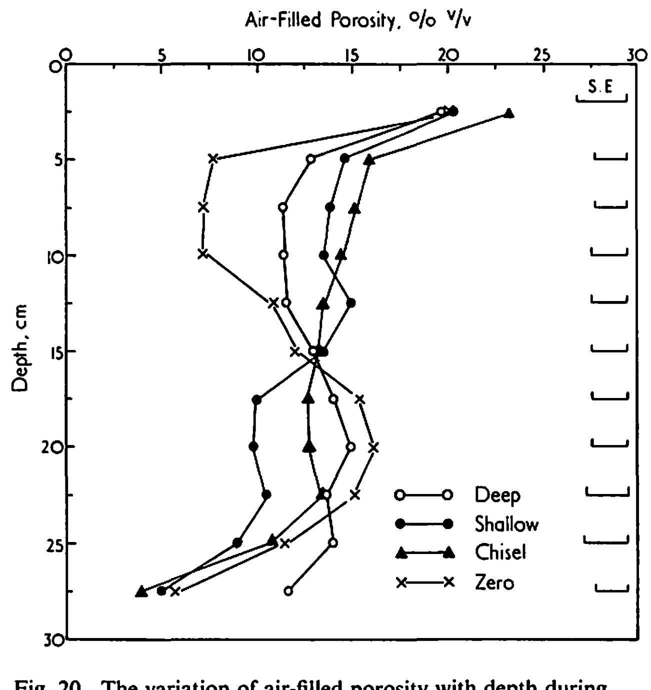


Fig. 20. The variation of air-filled porosity with depth during the growth of spring barley according to the type of ploughing used in the autumn.

ballasting which would otherwise not be required. The elimination of the tractor wheel from the furrow and a reduction in the amount of traffic on seedbeds and for harvesting would be beneficial. Looking further ahead the development of automated multi-wheel tool carriers and even a return to winch-operated systems may provide opportunity to reduce compaction as well as labour costs.

The economics of a reversal of current trends in machinery design and soil management are, as yet, uncertain but the seriousness of the present situation does not seem to be in doubt. We can continue the use of equipment giving rise to high compaction during tillage, spraying and harvesting operations if we accept the increasing expense of the remedial measures such as ploughing, subsoiling and the high tillage costs for clod control without any assurance that soil productivity can be maintained. Alternatively we can attempt to develop low compaction techniques in which the consequent reduction in soil working required would bring savings in the horsepower requirements per acre. This choice perhaps represents one of the most critical aspects of our approach to soil productivity today and the NIAE Scottish Station will continue and intensify its research on the theoretical and practical aspects of compaction for which this report serves as an introduction.

11. Conclusions

The passage of agricultural machinery over field soils results in increases in bulk density due to compaction. The vertical and horizontal extent of bulk density changes can be conveniently measured with gamma-ray transmission equipment. When heavily laden wheels run over cultivated soils, bulk density increases can be detected to the depth of ploughing. The values for bulk density and air-filled porosity which have been measured in the crop root zone following compaction suggest that adverse crop responses are likely to result, especially during periods of high soil moisture content. Although compaction due to the passage of wheels can never be eliminated there appear to be several ways in which its incidence could be reduced.

Summary

Changes in soil management and machinery usage in recent years appear to be responsible for an increase in soil compaction and there is evidence that this has resulted in a deterioration in soil physical conditions. Soil compaction in the field is a complex process in which several soil and load characteristics interact. The vertical and horizontal distribution of changes in bulk density and air-filled porosity resulting from compaction can be studied with gamma-ray transmission equipment. Compaction occurs during seedbed preparation, spraying and harvesting operations as well as during tillage. Because of the deleterious effects of compaction on subsequent crop growth extra tillage is frequently required for both the topsoil and subsoil. Compaction is also likely to influence the hydrological balance of the soil and the incidence of clods at potato harvest. Both the incidence and adverse effects of compaction are more probable when soils are moist. Soil compaction can be reduced in a number of ways but the economics of changes in current machinery design and soil management practices need to be established.

Acknowledgements

This work was carried out under the direction of Dr. I. M. Robertson. The author is grateful for assistance received from Mr. C. A. Carlow, Mr. D. J. Campbell and Mrs. S. M. Herkes.

References

1. Scott, J. *Text-book of Farm Engineering.* Crosby Lockwood, London, 1908.
2. Rowsell, J. 'What has changed?' *Rep. Proc. 21st Oxf. Fmg. Conf.*, 1967, 136-145.
3. Hughes, C. 'Soil fertility'. Parliamentary Debates (Hansard), 1969, **792**, **27**, 296.
4. Waller, R. 'Editorial: Agriculture—the suicidal industry'. *J. Soil Ass.*, 1969, **15**, **6**, 307-312.
5. Van Ouwerkerk, C. 'Farm mechanization and soil structure'. *Neth. J. Agric. Sci.*, 1969, **17**, 20-26.
6. Crompton, E. 'Soil structure'. N.A.A.S. Q. Rev., 1958, **41**, 6-15.
7. Davies, D. B. 'Soil compaction'. *Fmrs' Wkly*, Feb. 21, 1969, 51, 54, 55,
8. Hakansson, I. 'Model experiments in the field for studying soil tillage'. *Grundförbättring*, 1966, **19**, 111-116.
9. Lull, H. W. 'Soil compaction on forest and range lands'. *Forest Service U.S.D.A. Misc. Publ.*, 1959, **768**.
10. 'Proceedings of Conference on soil compaction'. *Grundförbättring*, 1966, **19**, 1-227.
11. Gill, W. R. and Vanden Berg, G. E. 'Soil dynamics in tillage and traction'. *U.S.D.A. Agric. Handbook*, 316. Government Printing Office, Washington, 1967.
12. Road Research Laboratory. 'Soil Mechanics for Road Engineers'. H.M.S.O., London, 1952.
13. Foster, C. R. 'Field problems: Compaction'. In *Foundation Engineering*, 1000-1024. McGraw-Hill, N.Y., 1962.
14. Soane, B. D. 'The effect of agricultural implements and traffic on soil bulk density using gamma-ray techniques'. Ph.D. Thesis, University of Edinburgh, 1969.
15. Li, C. Y. 'Basic concepts on the compaction of soil'. *Proc. Am. Soc. Civ. Engng, J. Soil Mech.* Found. Div., Paper 862 20 pp., 1956.
16. Felt, E. J. 'Compactibility'. In 'Methods of Soil Analysis'. **1**, 400-412. *Am. Soc. Agron.*, Madison, 1965.
17. British Standards Institution. 'British Standard 1377: 1967. Methods of testing soils for civil engineering purposes'. British Standards Institution, London, 1967.
18. Bruce, R. R. 'An instrument for the determination of soil compactibility'. *Proc. Soil Sci. Soc. Am.*, 1955, **19**, 253-257.
19. Mazurak, A. P. and Chesnin, L. 'Interaction of soil compaction, form and rate of iron application on the growth of soybean varieties'. *Trans. 8th Int. Congr. Soil Sci.*, 1964, **2**, 587-597.
20. Nichols, M. L. and Reaves, C. A. 'Soil structure and consistency in tillage implement design'. *Agric. Engng*, St. Joseph, Mich., 1955, **36**, 517-520, 522.
21. Day, P. R. and Holmgren, G. G. 'Microscopic changes in soil structure during compression'. *Proc. Soil Sci. Soc. Am.*, 1952, **16**, 73-77.
22. Swanson, C. L. W. 'Some physical facts about Connecticut soils'. *J. Soil Wat. Conserv.*, 1954, **9**, 132-137.
23. Free, G. R., Lamb, J. and Carleton, E. A. 'Compactibility of certain soils as related to organic matter and erosion'. *J. Am. Soc. Agron.*, 1947, **39**, 1068-1076.
24. Soane, B. D. 'The ground pressure of wheels and tracks'. Power Farming 1970. **44**, **4**, 40, 41, 43, 44
25. Söhne, W. 'Fundamentals of pressure distribution and soil compaction under tractor tires'. *Agric. Engng, St. Joseph, Mich.*, 1958, **39**, 276-281, 290.
26. Lambe, T. W. 'Soil stabilization'. In 'Foundation Engineering'. 351-437, McGraw-Hill, N.Y., 1962.
27. Cooper, A. W. and Reaves, C. A. 'Stress distribution in the soil under tractor loads'. *Trans. 5th Int. Congr. Agric. Engng* (1958), 1960, **2**, 1190-1198.
28. Davies, C. 'Further investigation into penetrability of steel points and soil consolidation'. *J. South-eastern Agric. College*, (*Uni. London*), 1933, **32**, 84-94.
29. Greacen, E. L., Farrell, D. A. and Cockroft, B. 'Soil resistance to metal probes and plant roots'. *Trans. 9th Int. Congr. Soil Sci.*, 1968, **1**, 769-779.
30. Fountaine, E. R. and Payne, P. C. J. 'The effect of tractors on volume weight and other soil properties'. *Nat. Inst. Agric. Engng*, Case study 17, 1952.
31. Soane, B. D. 'A gamma-ray transmission method for the measurement of soil density in field tillage studies'. *J. Agric. Engng Res.*, 1968, **13**, **4**, 340-349.
32. Baganz, K. and Kunath, L. 'Some measurement of stress and compaction under tractor wheels and tracks.' *Dt. Agrartech.*, 1963 (G), **13**, **4**, 180-182.
33. Reichmann, E. 'Determination of soil compaction due to travel over the soil of tractors and farm machines'. *Mitt. Bund Vers Anst. Landw. Masch., Wieselburg.*, 1965 (G), **11**, **4**, 299-325.
34. Steinbrenner, E. C. 'The effect of repeated tractor trips on the physical properties of forest soils'. *Northwest Sci.*, 1955, **29**, 155-159.
35. Goss, M. J. and Walter, C. H. S. 'The effect of mechanical resistance on the growth of plant roots'. *A. R. C. Letcombe Lab. Ann. Rep.* (1968), 1969, 27-28.

36. VEIHMEYER, F. J. and HENDRICKSON, A, H. 'Soil density and root penetration'. *Soil Sci.*, 1948, **65**, 487-493.
37. HAWKINS, J. C. 'Cultivations'. *Rep. Nat. Inst. Agric. Engng* (1958-1959)., S175-S181, 1960.
38. ROSENBERG, N. J. 'Response of plants to the physical effects of soil compaction'. *Adv. Agron.*, 1964, **16**, 181-196.
39. DE ROO, H. C. 'Root development in coarse textured soils as related to tillage practices and soil compaction'. *Trans. 7th Int. Congr. Soil Sci.*, 1960, **1**, 622-628.
40. JAMISON, V. C., REED, I. F., STOKES, C. M. and CORLEY, T. 'Effect of tillage depth on soil conditions and cotton plant growth for two Alabama soils'. *Soil Sci.*, 1952, **73**, 203-210.
41. GREENWOOD, D. J. 'Effect of oxygen distribution in the soil on plant growth'. In 'Root Growth'. 202-223, Butterworths, London, 1968.
42. ERMICH, D. 'Effect of bulk density of soil on plant growth and yield'. *Sb. Ref. Mezin. Ved. Symp. Brne.*, (1966), 1968 (G), 69-75.
43. ADAMS, E. P., BLAKE, G. R., MARTIN, W. P. and BOELTER, D. H. 'Influences of soil compaction on crop growth and development'. *Trans. 7th Int. Congr. Soil Sci.*, 1960, **1**, 607-615.
44. FLOCKER, W. J., VOMOCIL, J. A. and VITTUM, K. T. 'Response of winter cover crops to soil compaction'. *Proc. Soil Sci. Soc. Am.*, 1958, **22**, 181-184.
45. WITTSELL, L. E. and HOBBS, J. A. 'Soil compaction effects on field plant growth'. *Agron. J.*, 1965, **57**, 534-537.
46. TAYLOR, H. M. and HENDERSON, D. W. 'Some effects of organic additives on compressibility of Yolo silt loam soil'. *Soil Sci.*, 1959, **88**, 101-106.
47. PIZER, N. H. 'Soil structure in farming'. *J. R. Agric. Soc.*, 1961, **122**, 7-25.
48. HAWKINS, J. C. and BROWN, N. T. 'Tillage practices and mechanisation'. *Neth. J. Agric. Sci.*, 1963, **11**, **2**, 140-144.
49. WIND, G. P. 'Soil improvement'. *Instit. Land Water Man. Res., Wageningen, Tech. Bull*, 1967, **60**, 52-60.
50. WESSELING, J. 'Hydrology, soil properties, crop growth and land drainage'. *Instit. Land Water Man. Res., Wageningen, Tech. Bull*, 1968, **57**.
51. ERICKSON, A. E., HANSEN, C. M. and SMUCKER, A. J. M. 'The influence of subsurface asphalt barriers on the water properties and productivity of sand soils'. *Trans. 9th Int. Congr. Soil Sci.*, 1968, **1**, 331-337.
52. LYLES, L. and WOODRUFF, N. P. 'Surface soil cloddiness in relation to soil density at time of tillage'. *Soil Sci.*, 1961, **91**, **3**, 178-182.
53. VOMOCIL, J. A. and FLOCKER, W. J. 'Degradation of structure of Yolo loam by compaction'. *Proc. Soil Sci. Am.*, 1965, **29**, 7-12.
54. HOSKYNS, C. W. 'Talpa: The chronicles of a clay farm'. Longman, Brown, Green, Longmans, and Roberts, London, 1857.
55. WHYBREW, J. E. 'Wheat without ploughing'. *Agriculture*, 1969, **76**, **10**, 497-501.
56. VAN OUWERKERK, C. 'Two model experiments on the durability of subsoil compaction'. *Neth. J. Agric. Sci.*, 1968, **16**, 204-210. □

Cultivations

DISCUSSION
(First Session)

Chairman: H. C. G. HENNIKER-WRIGHT, FI Agr E, Mem ASAE*

Conducted during the Annual Conference of the Institution in London on 12 May 1970

MR J. C. HAWKINS (National Institute of Agricultural Engineering) said he had been quoted in Section 8.1 of Dr Soane's paper. However, as only part of a paragraph had been quoted, Mr Hawkins said he would like to read from the full text of what he had actually written in 1959, which was as follows. 'Particularly in areas like California, where much levelling is needed for surface irrigation, and on reclaimed open cast sites in this country, there are signs that heavy traffic is producing ill-effects. Attempts have been made to measure the soil consolidation, in terms of increase in bulk density, although this method is fast losing favour as a guide to compaction, because different soils with the same bulk density can have such different properties. Generally speaking, however, while an increase has been established as a result of the passage of tractors, it has reached a level far below what is accepted as too dense for plant roots to penetrate, yet the ill-effects of tractor wheel marks do exist. On wet land and on heavy soils, it is often possible to see a poorer crop in the wheelmarks and sometimes water will stand in them when the rest of the field is dry'.

Mr Hawkins also called attention to a paper given by Dr Eavis at the Agricultural Engineering Symposium of the Institution at Silsoe in 1967, which had examined the relationship between bulk density and root development, working at levels up to about 1.7 g/cm^3 Dr Soane quoted maxima of around 1.5, or just over, but Eavis was getting roots growing at levels as high 1.7. There was a danger of following a line of argument rather like this: loaded wheels caused compaction, compaction caused resistance to root penetration, resistance to penetration restricted roots, restricted roots meant lower yields and loaded wheels therefore meant lower yields. Mr Hawkins did not think this chain was proven. In fact another thing that Eavis had established was that resistance to root penetration depended on moisture tension. One should be careful to avoid suggesting that compaction from tractor weight was the full story. There must be many other effects brought about by tractor wheels: one could produce instances of ill-effects brought about by wheel slip and by the sort of kneading and puddling effects of the pneumatic tyre which were not necessarily due to compaction, or produced the effects that one would expect compaction to produce. It was necessary to look at increase in bulk density closely as only one possible factor in the ill-effects which were known to occur behind traffic.

MR J. V. FOX (Bomford & Evershed Ltd.) said the message of this conference appeared to be that as far as possible we should keep off the land and keep cultivation to an absolute minimum, commensurate with maintaining a reasonably adequate environment for the crop. There were many who had had experience of over-cultivation in these terms, but it would be of considerable interest to know the extent of the problem. Cultivations must cost the farming industry an astronomical amount of money annually and the saving of even five to ten per cent of these costs would significantly influence the economy of farming. Mr Fox wondered if either of the first two speakers would care to hazard a guess at the potential saving that might be affected if in fact this were put into practice and cultivations were kept to an absolute minimum.

Mr Fox said there were one or two other points on which he would like clarification. Dr Soane had mentioned that

* President of the Institution.

ploughing caused bad compaction and yet he had also said in his paper that they had found that ploughing seemed to give the best physical conditions as indicated by crop yield results in certain tests. Could he elaborate on on that? In relation to the grid pattern effect of the typical seed bed preparation as shown by Dr Soane the potential for compaction had looked pretty alarming. Could he comment on the effect of a time lapse between compaction and cultivation to remove the compaction? For instance, other factors being equal, would the compaction caused by a ballasted tractor be removed as effectively by cultivation, say three months later, as by a cultivator actually mounted on the tractor which was causing the compaction?

DR B. D. SOANE (Author of Paper II) first of all apologised to Mr Hawkins if the latter felt he had been quoted out of context, as he had not wished this to be the case. In answer to Mr Fox, Dr Soane said there was a possibility of considerable cost reduction as a result of restricting the number of trips which tractors were having to make over the soil. He did not feel competent to answer in terms of pounds, shillings and pence profit per acre. Other people in the room could no doubt do that much better, but there was work going on at the National Institute of Agricultural Engineering at Wrest Park on this very factor, and possibly their representatives here would be interested to comment on that.

The question of crop yield responses in relation to density or compaction changes was a very difficult question and there was still a great deal of information that had to be gathered. Some of the available information was completely conflicting. Some workers had quoted quite remarkable yield reductions from changes in density far smaller than the densities that he had shown in the illustrations in his paper. On the other hand, there were those who had induced density changes which had been quite large and had noted only very small changes either in the root growth or in yield. The translation from laboratory type experiments into the field was a very hazardous process and must always be accompanied by an appreciation of the fact that we really knew very little about the real environment of roots in our field soils. There was evidence, for instance, from the sort of work going on at the Letcombe Laboratory, which suggested that under laboratory conditions a considerable constriction in root penetration was not necessarily reflected at all in terms of yield. The crop, if provided with water and nutrients in the surface to a depth of four or five centimetres might have the ability to gather these nutrients, grow successfully and produce a satisfactory crop.

But when one started going out in the field all sorts of other factors became critical. Water was not always readily available. Nutrients were not always readily available throughout the root zone and there might be periods of drought or periods of excessive wetness. These periods of excessive wetness could be quite long, and this particularly applied in the north of the country where in some years fields could be, if not under water, at least saturated or very nearly saturated for several weeks during the growing season, This had happened two or three years running in May which, was a very critical time from the point of view of the crop and if that crop was growing on a soil which was highly compacted, in zones or bands, at a depth of some ten to twelve centimetres, as would apparently be the effect if it had been cultivated in the way he had described, it was far from being a satisfactory root medium. If the whole hydrology of the soil was in a very poor state, it would remain wet much longer than was desirable and the compaction was one of the causative factors of this unsatisfactory state. The compaction also occurred of course in the subsoil and the remarkable responses which had been obtained in some parts of the country to subsoiling suggested that many of our soils were in fact in a less than desirable physical condition. Dr Soane said he agreed the mechanism was not always compaction, but there was an accumulating amount of evidence which seemed to point in that direction. It was possible, however, that he had misjudged the information or misread the reports which were available.

Lastly, Dr Soane dealt with the question of the grid pattern of wheel tracks and the extent to which the problem of a ballasted tractor perhaps producing some compaction at seed bed could be relieved by tillage or cultivation subsequently, some months later. In general, he said he thought that the the use of a tine following tractor wheels during seed bed operations, during spraying operations and so on, would produce a lot of problems. It might relieve the compaction which had occurred below the wheel, but it was unlikely that one could put a tine into the necessary depth to relieve all that compaction without introducing a lot of other problems. Dr Soane acknowledged that the experience of anybody who had tried to do this would obviously be of more value than anything he could say because he had not seen it done, but on the whole a lot of the compaction which occurred during seed bed operations, during spraying operations and so on was not relieved ; this was the practical case. What we ought to do about this was open to question. There were some people who felt we should pay a lot more attention to the type of machinery we used for these tillage seed bed operations, while others perhaps believed we should only do it at the right moisture content. Again, there were others who believed, in fact, that we should not do it at all, but that we should just push the seed into the uncultivated ground. There were all sorts of arguments in different directions, with no clear picture yet as to what was going to be the best solution. It would doubtless vary according to soil type and climate.

MR L. R. BOMFORD (Farmer) said he had heard some mention today of organic matter in the soil but none of soil bacteria, and these were extremely important to the subject under discussion. He gave, as an instance, ploughing in straw about seven inches in Hampshire land, leaving the land to lie for a couple of years, and then ploughing it up again. That straw would be just blackened and flat, while straw in the top two or three inches would have disappeared in under the year.

Another aspect of soil bacteria was the breaking down of ammonia into plant food, and possibly that aspect was more important than some of the others that had been discussed this morning, which were much more mechanical.

Mr Bomford said he would like to know what work had gone on in that direction, because the bacteria in our soil were extremely important.

MR N. J. BROWN (Author of Paper I) said he could quite understand the observations concerning the burial of straw to seven inches, which later came up black and smelly, almost as it had been put down. This could occur even on sandy soils, especially on very fine sands where fine particles and poor structure resulted in very tight packing. An anaerobic situation occurred and the whole zone became very unsuitable for plant life. Another aspect of micro-organisms within the soil was that they would compete with the plant for the oxygen that is available in the soil. Mr Brown agreed that micro-organisms were necessary to break down organic matter and other substances, but if a situation occurred when oxygen supply to the roots became, or approached, a limiting condition then, in competition with plant roots, perhaps these organisms would have preferential usage of the available oxygen.

MR C. HULL (David Brown Tractors Ltd.) said he would like to take up one particular point which was the happy abandon with which people jumped to making initial assumptions. An example was this argument that as tractors became heavy and more powerful, so soil was becoming more compacted. If this was so, why could we not see some diagrams to show that tractors today produced more soil consolidation than they did a decade ago? How did we compare with steam tractors of tremendous weight and very low powers of many decades ago? Mr Hull said he found it hard to believe that heavier and more powerful tractors did compact soil more. The air pressures used in the tyres had not changed significantly since the introduction of pneumatic tyres and maximum soil pressures were reputed to have some relationship to the air pressures. His own feeling on this subject was that clods were the result of working soil and running on soil at a time when tractors should not be in the field at all.

Dr Soane replied that there were many aspects to that question, some of which were capable of receiving an answer and some of which were not. Unfortunately the trends in tractor design over the last fifty years had apparently not been followed by compaction studies. It was only very recently that it had become possible to measure compaction adequately and therefore it was not possible to quote figures to suggest any sort of parallel between the weight of the average tractor over a long period of time and the densities in our soils. Dr Soane said that this information, to his knowledge, was not available.

There were some studies from Holland which he had quoted in his paper, such as the work of Van Ouwerkerk at Groningen. The latter had made some effort to study the structural effects on farms using animal power, which had no tractors at all in comparison with farms which had been actively cultivated by tractors over the last ten or fifteen years; he had come up with the statement that the soil structure was in a less favourable condition on the fields which had been cultivated by tractors. This work had been carefully done for very limited conditions. It was one of the very few studies attempted in this field and there were very few opportunities now for doing this. A lot of our thinking on this subject had in the past been pure guess-work. One knew that tractors were becoming heavier; therefore many had assumed that they must be creating more compaction.

Coming to the second point about surface pressures, Dr Soane said he thought this was coming a little more into the field in which one could have more specific ideas. It was true that if one could suitably increase the width of tractor tyres and increase the number of wheels if necessary, the average surface pressure could be kept at a reasonable level in spite of a considerable increase in weight. It had been shown however that the compaction response to an applied surface load was not solely a question of the surface pressure. On the theoretical grounds both the surface area under load and the total weight which was on the soil affected the depth to which compaction occurred. There was evidence that this was the case in practice. Surface pressure alone was not an adequate criterion of compaction hazard. As one increased the weight, the width of the tyre would be increased and therefore the area of the field which was being run over would be greater. The counter argument to that of course was that tractors were now so powerful and the width of working so wide that they travelled a shorter distance per acre than previously. This point about the surface pressure effect was important because it was believed by some that all one had to do was provide suitable wheels, more wheels, wider wheels, greater diameter wheels and thus hold the situation at least at current levels.

With regard to Mr Hull's final point, Dr Soane said that in modern farming one very often found that even the best farmer had to carry out certain operations at times when he would admit that he did not like doing so. The farmer would possibly admit that his grandfather would not have done it at that time and it seemed that economic pressures were nowadays forcing farmers to put machinery on the soil at certain times of the year when they knew that they should not be doing so. One had to recognise that with a very limited labour force this might be something we had to live with. □

INDEX TO ADVERTISERS

Better Use of Farm Machinery in Developing Nations

Sir,

The scene is a too sadly familiar one in the developing countries of Africa, Asia and South America. A tractor splutters its way across a field and finally grinds to a halt. The driver starts poking around to find the fault with little idea where to look, or what to do even if he can locate the trouble. At best he will waste a great deal of time effecting a repair. Or he may walk away to get a mechanic, which usually means very long delays. At worst he will attack the offending machine with an adjustable wrench and probably do a lot of damage. And the original trouble may only have been a blocked jet or a loose battery connection.

As farm machinery gets more sophisticated and complex it becomes difficult for operators in developing nations to keep it working efficiently. Even where the operator has had a minimum of formal training, his low literacy and comprehension levels, coupled with poor mechanical sense, mean the average instruction book or maintenance manual is virtually incomprehensible to him.

My colleagues and I have seen this situation in many developing countries where mechanisation is being introduced to help the urgent task of increasing food production. The machinery arrives fresh from the factory looking efficient and impressive. But give it a few weeks out on the farm and the best engineered piece of equipment not backed by proper training and instructional procedures will soon end its useful life and become another lump of rusting metal.

From the enquiries we have been making recently in the agricultural machinery industry it seems that this is most often seen as an area of responsibility for the marketing and training people. It is presumed that they realise what the overseas markets require in this respect and the danger of losing repeat orders if machinery performs badly because its operational requirements are not fully understood. Of course, some manufacturers have quite a creditable record in this field. Others, many of them, have an incredible blindspot over this question.

I would respectfully submit to the learned members of the Institution of Agricultural Engineers that they have an ethical and moral responsibility to be more concerned with what happens to the products of their skill when used in the developing nations. The agricultural engineer has the knowledge and ability to make a significant contribution towards easing the hunger pangs afflicting most of the world's population. But after producing the machinery to increase food production, can you say your responsibility is ended and turn your back on these hungry millions?

Could not the engineer insist that he is always closely involved in overseas marketing right down to the ultimate user levels? The information he acquires from this exercise could contribute substantially to product design and development. Just as important, the engineer can bring his influence to bear in deciding how operating and maintenance instructions are communicated to the users.

A lot can be done quite cheaply and quickly. For example, a colleague of mine has designed for use in Africa simple cards encased in plastic to be attached to tractors and providing even illiterate drivers with a visual check list to go through in the event of a breakdown. We are at a loss to understand why every tractor exported to the developing nations does not have such instructions. Many items of complicated machinery—complicated to the average African or Asian farm worker, if not to us—have inadequate instructions often not even written in the local language. It's like giving an army recruit his first rifle and not telling him how the safety catch works.

Also, I often wonder how many engineers are conscious of the technically unsophisticated level in developing countries at which many of the orders for farm machinery are placed.

This frequently leads to the purchase of equipment which is good of its kind but not appropriate to the task it is to carry out. The salesman gets his order, but in the long term the customer is usually dissatisfied and the equipment—and, by inference at least, the engineer also—gains an undeservedly adverse reputation.

Those of us involved with the developing nations are concerned with many such questions and I think the views of agricultural engineers and their more active participation in these issues would be of immense benefit. I am currently researching this whole field and would welcome any comments, information or suggestions from Institution members who can contact me at Development Services International, 35 Piccadilly, London W.1. Telephone 01-734 1821.

C. F. HAYNES
Communications Consultant
Development Services International
London W.1.

Metrication

Sir,

In the Summer 1970 issue of the *Journal* (Volume 25 No. 2) you have published on page 60 certain information concerning the change to SI units. Whilst you have quite correctly prefixed the table of SI units with the heading 'Every Day Units' the impression received from reading the preceding paragraphs is that these Every Day units are part of the SI system which is to be adopted by this country. This could be misleading as the following units which you have listed are *non* SI units for limited use only.

Unit	*Symbol*
°Celsius	°C
litre	litre
hectare	ha
hour	h
minute	min

It may be of interest to readers of the *Journal* to know that the SI units are divided into primary and supplementary units and that the primary units are the metre, kilogramme, second, ampere, degree kelvin and candela.

I was also interested to see on page 63 the report of the Chairman of the Metrication Board, Lord Ritchie-Calder, in which he says the whole world will predictably be metric by the end of the 1970s. Surely this is not so, for the United States of America is not metric and as far as I am aware has no plans to go metric by the end of the 1970s.

O. J. H. STATHAM
(Member)
Machinery Officer
Potato Marketing Board,
London S.W.1.

Pen Friend Wanted

Sir,

Last year we were responsible for arranging a fortnight's visit for a party of farmers and others from Czechoslovakia. Since they returned to their country a number of them have written and have requested to be put in touch with somebody they could write to with regard to their own particular post. We have succeeded in finding correspondents for most of the people requesting it but one of the party would very much wish

Please turn to page 132

Examination Board in Agricultural Engineering

National Diploma in Agricultural Engineering

1970 Examination Results

1 Agricultural Approach Passes

		Subjects passed with Distinction	Subjects passed with Credit
a. Essex Institute of Agriculture	Barrett, A. J.	—	FME, EST, FMM, FBM
	English, S. V.	—	FME, EST, FE
	Heath, R. P.	—	EST, FMM, FBM
	Jones, G. O. S.	EST	FMM, BS
	Malec, S. M.	—	FME, EST
	Morgan, D. N.	EST	FME, FMM, BS
	*Moseley, B. A.	EST	FME, FMM, BS
	Noble, S. W.	FME, EST	FBM
	Northridge, F. J.	—	FME, EST, FMM, FE
	Robinson, M. D.	—	EST, FE
	Sewell, J. J.	FE	FME, EST
	Walker, J. G.	—	FME, EST, FMM, BS
	Watson, W. J.	—	FME, FE
	Willy, R. J.	—	FMM
b. West of Scotland Agricultural College	Brackenridge, J. McD.	—	FME, FMM
	Brown, S. R. H.	FME, BS	EST, FMM
	Chaudhary, F. M.	—	FMM, BS
	Dent, A. A.	EST	FME, FMM, BS
	Halder, F. J.	—	FMM
	Langley, A.	EST, FMM	FME, BS
	Leggatt, R.	—	FME, EST, FMM
	McAuslan, J. T.	—	FME, EST, FMM, BS
	McCracken, W. R.	—	FME, FMM, BS
	Sivanesan S.	—	FME, EST

2 Engineering Approach Passes

a. Essex Institute of Agriculture	Grossmith, J. A.	—	AEPAE, MCAP, FE
	Lavers, A.	—	MCAP, FMM, BS
	Lewis, B. C.	FE	AEPAE, MCAP, FMM
	Ouvry, P. G.	—	AEPAE, MCAP, FMM, FE
	Poole, C. R.	FMM	AEPAE, MCAP, BS
	Robertson, S. W.	—	AEPAE, MCAP, FMM, BS
	Tulloch, A. J. H.	FMM	AEPAE, MCAP, FE
	Turner, J. P.	—	FMM
	Lewis, P. G.	—	AEPAE, MCAP, FMM

		Subjects passed with Distinction	Subjects passed with Credit
b. West of Scotland Agricultural College	Atoo, C.	—	—
	Corner, A. R. I.	—	—
	Dean, G. W. C.	FE	AEPAE
	Dean, R. J.	FE	FMM
	Delgoda, R. S.	—	FMM, FE
	Erskine, R. J.	—	AEPAE, FE
	Gardner, D. W.	FE	AEPAE, MCAP
	Heygate, C. N. St. C.	—	FE
	Ilamurugan, C. P.	—	FE
	Johnson, R. A.	—	FE
	*Jones, D. J. M.	FE	AEPAE, MCAP, FMM
	Lavender, J. A.	AEPAE, MCAP, FE	FMM
	Mander, C. E.	FE	AEPAE, MCAP, FMM
	Poolman, J. R.	—	AEPAE
	Purchas, M. D.	FE	AEPAE
	Sims, K. J.	FE	AEPAE, MCAP, FMM

Please turn to next page

ND Agr E 1970 Results—*from previous page*

		Subjects passed with Distinction	Subjects passed with Credit
b. West of Scotland Agricultural College (*continued*)	Theakstone, D.	—	AEPAE, MCAP
	Thornton, C. A.	—	AEPAE
	Webb, D. C.	—	AEPAE, MCAP, FMM, FE
	Woodward, R. E.	FE	MCAP, FMM
	Alagendra, A. R.	—	FE
	Ellin, C. R.	—	—
	Lee, R. G.	—	FE
	Mears, A. J.	—	—
	Mensah, J. A.	—	—
	Soobrian, L. H. P.	—	FE
	X Mountstevens, M. J. W.	—	BS

J. A. C. Gibb
Chairman
J. K. Bennett
Secretary

GLOSSARY OF SYMBOLS AND ABBREVIATIONS

X	External Candidates
*	Holding Shell-Mex & B.P. Bursary Award
AEPAE	The Application of Engineering Principles to Agricultural Equipment
MCAP	Mechanization of Crop and Animal Production
FME	Farm Mechanization Equipment
EST	Engineering Science and Technology
FMM	Farm Mechanization and Management
FE	Field Engineering
FBM	Farm Buildings and Mechanization
BS	Business Studies

□

VIEWPOINT—*from page 129*

to correspond with a person with a similar post to himself. I have been unable to think of anybody who might be interested in his particular field of activity and I quote from his letter in case you may be able to suggest somebody who has similar interests and would like to correspond on technical matters with him.

'I should very like to write with somebody in England and so better my English and also to change some experiences. But I am at a loss, that such a branch like I have there is not in your enterprises. I am chief econom and I direct economical provides, plans, wages and administrative works in small enterprise, where is employed at about 260 persons. Our enterprises makes services for agriculturists, mainly agriculture works for co-operatives, repairs of tractors and other agricultural machines and teach apprentices for repairs'.

If you can suggest anybody I should be most grateful.

R. S. C. READMAN

Principal,
Lindsey College Agriculture,
Riseholme, Lincs.

(Replies will be forwarded—Hon. Ed.)

Credit Note

Sir,

Having received the issue of I Agr E (Volume 25, No. 1, Spring 1970) and gone through it, I can't help writing this letter to you to let you know that this particular issue of our Institution *Journal* has been very well produced. Needless to say, I hope future issues will be just as good.

M. Z. MANAF
(Associate)

Salangor,
West Malaysia

(We would like to thank Mr. Manaf and the many other readers who have expressed similar approval—Hon. Ed.)

Imagination and Innovation

Sir,

I would appreciate having your assistance in making contact with agricultural engineers (faculty staff, graduate students, independent consultants) capable of designing and developing new agricultural machinery on an extra-curricular basis.

We seek to contact imaginative and innovative engineers, and are prepared to arrange generous profit-sharing terms with qualified parties.

You are free to circulate this letter as may be required, and I look forward to hearing from interested engineers and, as well, to having suggestions which you may care to make.

B. S. MOORE

Manager,
New Product Research,
Dominion Bronze Ltd.,
Winnipeg, Canada.

(Replies will be forwarded—Hon. Ed.)

The Journal — Summer 1970 issue

Sir,

You have kindly given acknowledgement to the Electricity Council for the use of the front cover illustration in the above issue of the *Journal.* I find that one of the two authors of Farm Electrification Handbook 18, Mr Graham Smith, is in fact very much indebted to Messrs. Matthews and Yates for the use of the diagram reproduced on the front cover. We would wish very much therefore, that the acknowledgement which you gave us should be re-addressed to Messrs. Matthews and Yates.

R. A. BAYETTO
(Fellow)

Marketing Department,
The Electricity Council,
London SW1.

□

admissions and transfers

At a meeting of the Council of the Institution on 23 July 1970 the following candidates were admitted to the Institution or transferred from one grade to another, as stated below.

ADMISSIONS

Member

Scott, A. H.	*Roxburghs*
Spence, M. (Mrs)	*Warwicks*

Associate

Blakely, G. E. R.	*Beds*
Brice-Baker, R. H.	*Hants*
Craig, H.	*Essex*
Culy, B. W.	*Kenya*
Dickie, J. R.	*N Ireland*
Fernando, E. C.	*Ceylon*
Field, A. W.	*Kenya*
Ions, K.	*Northumberland*
Llewellin, R. T. B.	*Nigeria*
Long, D.	*Bucks*
McSween, G. J.	*Jamaica*
Peters, R. J.	*Bucks*
Read, T. L.	*Kent*
Short, R.	*Hants*
Smith, R. B.	*Lincs*
Valentine, M. T.	*Warwicks*

Graduate

Blackford, R.	*Worcs*
Boys, P. D.	*Wilts*
Hawthorne, M. A.	*W Lothian*
Metianu, A. A.	*Ayrs*
Wilkes, J. M.	*Kent*

Student

Bedingfeld, D. G.	*Beds*
Brown, S. R. H.	*Lanarks*
Chaudhary, F. M.	*Lanarks*
Garwood, M. F.	*Hants*
Guess, R.	*Beds*
Harris, A. P.	*Beds*
Kramer, E.	*Beds*
List, E. J.	*Suffolk*
Ogumkoya, J. A.	*Nigeria*
Osibanjo Y. G.	*Nigeria*
Sangarapillai, S.	*Lanarks*
Smith, S. R.	*Somerset*
Whetnall, C. R.	*Somerset*

OBITUARY

The Council announces with deep regret the death of the following members of the Institution:

Christian G. R.	*Member*
Crabtree, G.	*Fellow*
Cottrell, F. B.	*Member*

TRANSFERS

Fellow

Lightwing, W. B.	*Yorks*
Rogers, H. B.	*Warwicks*
Weeks, F.	*Yorks*

Member

Evans, D. V.	*Lincs*
Leslie, W. A.	*Wilts*
Meek, N. W.	*Bucks*
Mundell, P. F.	*Herts*
Searle, M. S.	*Surrey*
Southcombe, E. S. E.	*Beds*

Associate

Evans, R. B.	*Cambs*
Heald, J. M.	*Lincs*
Ogidi, C. W.	*Lanarks*
Trevarthen, R. H.	*Leics*

Graduate

Apeaning J.	*Ghana*
Lamm, A. A.	*W Lothian*

Printed by The White Rose Press Mexborough and London

A modern tractor is an expensive investment. Every breakdown is an expensive waste of time. One way to keep your tractor hard at work: choose an oil with the right blend of base oils and chemical additives to match your tractor's complex needs.

Choose BP or Shell oils. You'll get quicker starting, cooler running and less wear – with an engine that's cleaner and less prone to rust and corrosion.

In short you'll get more of those precious hours of full-time performance from all your machinery.

Tractor Oils Universal • Series 3M Tractor Oils

CRC 1/70