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INSTITUTION NOTES

Annual Conference

Over 150 members and guests were present at the 1964 Annual Conference of the Institution. This took place within the lecture hall of The Institution of Mechanical Engineers at 1 Birdcage Walk, London SW1 on 28th April 1964.

After an informal foregathering over refreshments, members assembled for the morning session which began with a Paper entitled 'Theory and Practice in Off-the-Road Locomotion' by Mr A. R. Reece of the University of Newcastle. This was followed by the Annual General Meeting of the Institution. The afternoon was devoted to two Papers: 'Control of Environment for the Growth of Plants in Glasshouses' by Mr G. P. Shipway of The National Institute of Agricultural Engineering, and 'The Agricultural Tractor – Some Unorthodox Concepts' by Mr K. E. Morgan of the University of Reading.

The Conference was opened by Mr W. J. Priest, President of the Institution, who remained in the Chair for the whole of the morning's proceedings. Mr W. G. Cover, Vice-President, presided during the presentation of Mr Shipway's Paper, handing over the Chair to Mr J. H. W. Wilder, Vice-President and President-Elect, for the concluding paper by Mr Morgan.

Fully illustrated versions of all three Papers given at this Conference, together with summaries of the ensuing discussions, appear on pages 82 to 113 of this *Journal*. A Report of the proceedings of the Annual General Meeting will appear in the next issue.

Annual Dinner

This event, which took place during the evening of 28th April, proved to be a happy and successful culmination to the proceedings of the Annual Conference held earlier that day. A representative gathering of some 120 members and their friends attended this function at St Ermin's Hotel, London, the Guest of Honour being Mr J. D. F. Green, Chairman of the Agricultural Advisory Council for England and Wales. He proposed the Toast of 'The Institution of Agricultural Engineers' and the response was made by Mr W. J. Priest, President of the Institution, from the Chair. Other speakers were Mr W. P. Authers, President of The Agricultural Engineers Association, and Mr J. H. W. Wilder, a Vice-President and the President-Elect of the Institution.

A full report of the speeches at the Dinner will be found on pages 75-80.

Wakefield Memorial Lecture

The 1964 Wakefield Memorial Lecture, sixth in a series given annually in honour of the memory of Lord Wakefield of Hythe, founder of the Castrol Group of Companies and first President of the College of Aeronautical & Automobile Engineering, Chelsea, was delivered in Chelsea Town Hall, London, on 23rd April 1964 by Mr W. J. Priest, M.I.AGR.E., President of the Institution of Agricultural Engineers. The occasion was attended by a large audience composed of friends and students of the Chelsea College, which since 1950 has offered instruction in agricultural engineering to students from all over the world. Previous Wakefield Lectures have reflected the work of the College in Aeronautical and Automobile Engineering, and Mr Priest chose as his theme 'The Importance of Agricultural Engineering in Relation to Feeding the World'. The Lecture will appear in full in the next issue of the *Journal*.

British Conferences and Exhibitions

Forestry Exhibition, Camberley, Surrey

This Exhibition, of special interest to all who are in any way associated with forestry, will include latest developments in forest machinery and equipment. Displays will include tree-felling competitions and fire-fighting demonstrations. It will be held at Blackbushe, near Camberley, Surrey, on Wednesday and Thursday, 17/18 June 1964.

Further information may be obtained from the Secretary, Forestry Exhibition, Forestry Commission, 25 Saville Row, London W1.

Royal Show, Kenilworth, Warwicks

The Royal Agricultural Society of England announces that the 1964 Royal Show will take place at Stoneleigh Abbey, Kenilworth, Warwicks., from 7th July to 10th July inclusive. Further information of this event may be obtained from the Secretary and Technical Director of the Society at 35 Belgrave Square, London SW1.

Enterprise Scotland '64, Glasgow

To be held in Kelvin Hall, Glasgow, from 3-19 September 1964, this Exhibition will bring together under one roof a wide range of capital and consumer goods from engineering and wool-based industries to electronic and precision machinery products.

Further particulars may be obtained from the Exhibition Offices, 2 Woodside Terrace, Glasgow C3.

Overseas Agricultural Engineering Events

VIth International Congress of Agricultural Engineering Lausanne, Switzerland.

Organised by the Commission Internationale du Génie Rural (C.I.G.R.), this important Congress will conduct its proceedings from 21st to 27th September 1964, as announced in the July 1963 issue of the *Journal*. It is of special interest to note that this occasion coincides with the Swiss National Exhibition, also in Lausanne, which takes place only every 25 years and includes agricultural exhibits. Listed in the provisional programme of the Congress are such subjects as soil science and its application to agricultural engineering, drainage schemes, economics of irrigation, housing of livestock, pooling of machinery in co-operative farming and agricultural work study. Details of the Congress can be obtained from the Secretary, Institution of Agricultural Engineers.

Congress on Mechanisation in Horticulture, Budapest

Jointly with the Hungarian Society of Agricultural Sciences, the Hungarian Society of Mechanical Engineers announces details of the above Congress to be held in Budapest on 20th-23rd October 1964. Subjects to be treated will include mechanisation of soil cultivation, plant growing, plant protection, transport, gathering and processing. There will be displays of machinery employed in wine growing.

Particulars are available on application to the Hungarian Society of Mechanical Engineers, Budapest V, Szabadsag ter 17.

Land Drainage Course, Wageningen

The International Institute for Land Reclamation and Improvement and the International Agricultural Centre of Holland announce that their 3rd Post-Graduate Training Course on Land Drainage will be held at Wageningen, The Netherlands from 14th September to 18th December 1964.

Those wishing to participate are invited to contact the Director, International Agricultural Centre, 1 Generaal Foulkesweg, Wageningen, the Netherlands.

Appointments Service

Members are cordially reminded that a monthly list of situations vacant in the agricultural engineering industry, teaching and research, both in Great Britain and overseas, will be supplied on request.

Those wishing to avail themselves of this service should notify the Institution Secretary. It would be appreciated if members would inform the Institution of changes of appointment, in order that office records may be kept up to date and, where applicable, the circulation of lists from the Appointments Service terminated.

National Institute of Agricultural Engineering

Mr C. J. Moss, B.SC., M.I.MECH.E. has been appointed to succeed Mr W. H. Cashmore, as Director of the National Institute of Agricultural Engineering, when Mr Cashmore retires on 31st July 1964. Mr Moss was educated at Northgate School, Ipswich, and London University, where he obtained 1st Class honours in Mathematics and was awarded the Sir John William Lubbock Memorial Prize.

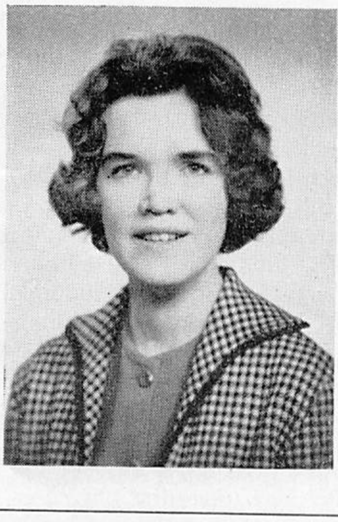
During the Second World War, Mr Moss worked in the aircraft industry and since then he has worked in the field of synthetic resin manufacture, with I.C.I., and was Deputy Director of the Central Engineering Establishment of the National Coal Board from 1958 to 1961, when he became Assistant Director-General in the Process Development Department of the N.C.B.

Correction

In the discussion to the Paper 'Safety Aspects of Tractor Cabs and Their Testing' by Mr T. C. D. Manby, published in the February 1964 issue of the *Journal*, a contribution appearing on page 67 is attributed to 'Mr J. M. Chambers (Harry Ferguson Research Ltd.)'. This is incorrect and should be amended to read 'Mr R. M. Chambers (Massey-Ferguson (U.K.) Ltd.'). The publishers regret any inconvenience or embarrassment to which this may have given rise.

Examination Board in Agricultural Engineering

APPOINTMENT OF BOARD SECRETARY



One consequence of the reorganisation which is taking place within the headquarters of the Institution of Agricultural Engineers is a decision to appoint a Secretary to the Examination Board in Agricultural Engineering. Miss J. P. Housley, B.A., has been appointed to this position as a result of a recommendation from the Examination Board, and took effect on 2nd April 1964. She will continue to be Assistant Secretary of the Institution.

Miss Housley, an Honours Graduate of London University, joined the Institution staff in 1960, and has had considerable educational and administrative experience, including a period in the U.S.A. on an international exchange scheme. In January 1963, she was appointed Assistant Secretary of the Institution, in which capacity she continued primarily to be engaged on education and examination work, whilst also assisting the Secretary in general administration.

The fact that the post of Examination Board Secretary has been created lends emphasis to the intensive work during the past year by the Examination Board in the complex development of a new pattern of examinations and other qualifications for Institution membership during the years immediately ahead.

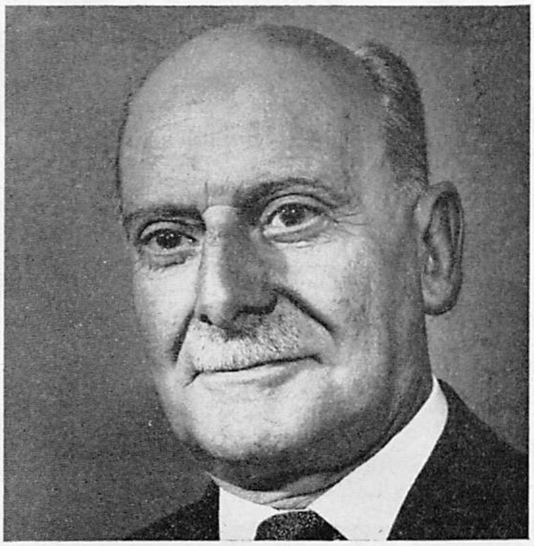
Mr W. H. CASHMORE, M.I.AGR.E.

The announcement has recently been made of the retirement in July 1964 of Mr W. H. Cashmore, C.B.E., B.A., C.I.MECH.E., M.I.AGR.E., Director of the NATIONAL INSTITUTE OF AGRICULTURAL ENGINEERING since 1947.

Mr Cashmore joined the forerunner of the N.I.A.E.—the Institute for Research in Agricultural Engineering at Oxford—in 1925. In the next few years he was to make a major contribution to the development of agricultural engineering through his work in connection with combine-harvesters and pick-up balers, and their introduction to this country. During the war years he played an important part in the Ministry of Agriculture's schemes for maximization of farm outputs. When the war ended in 1945 he was appointed Deputy Director of the Institute—its title having been changed to National Institute of Agricultural Engineering.

Shortly after the N.I.A.E. had been transferred to its present site at Wrest Park, Silsoe, Bedford, responsibility for its work was taken over by the Agricultural Research Council. Under Mr Cashmore's Directorship, development work and research into the problems of agricultural and horticultural engineering attained a high level of achievement. Important features of the N.I.A.E.'s post-war activities include the institution of the Users' Testing Scheme and the establishment of the Commonwealth Liaison Unit to further the development of overseas agriculture.

Mr Cashmore, who was awarded the C.B.E. in 1956, has rendered valuable service to the Institution of Agricultural Engineers as a member both of Council and Examination Board, as a Vice-President and as an Examiner for the National Diploma in Agricultural Engineering.



Mr ALEXANDER HAY, HON.M.I.AGR.E.

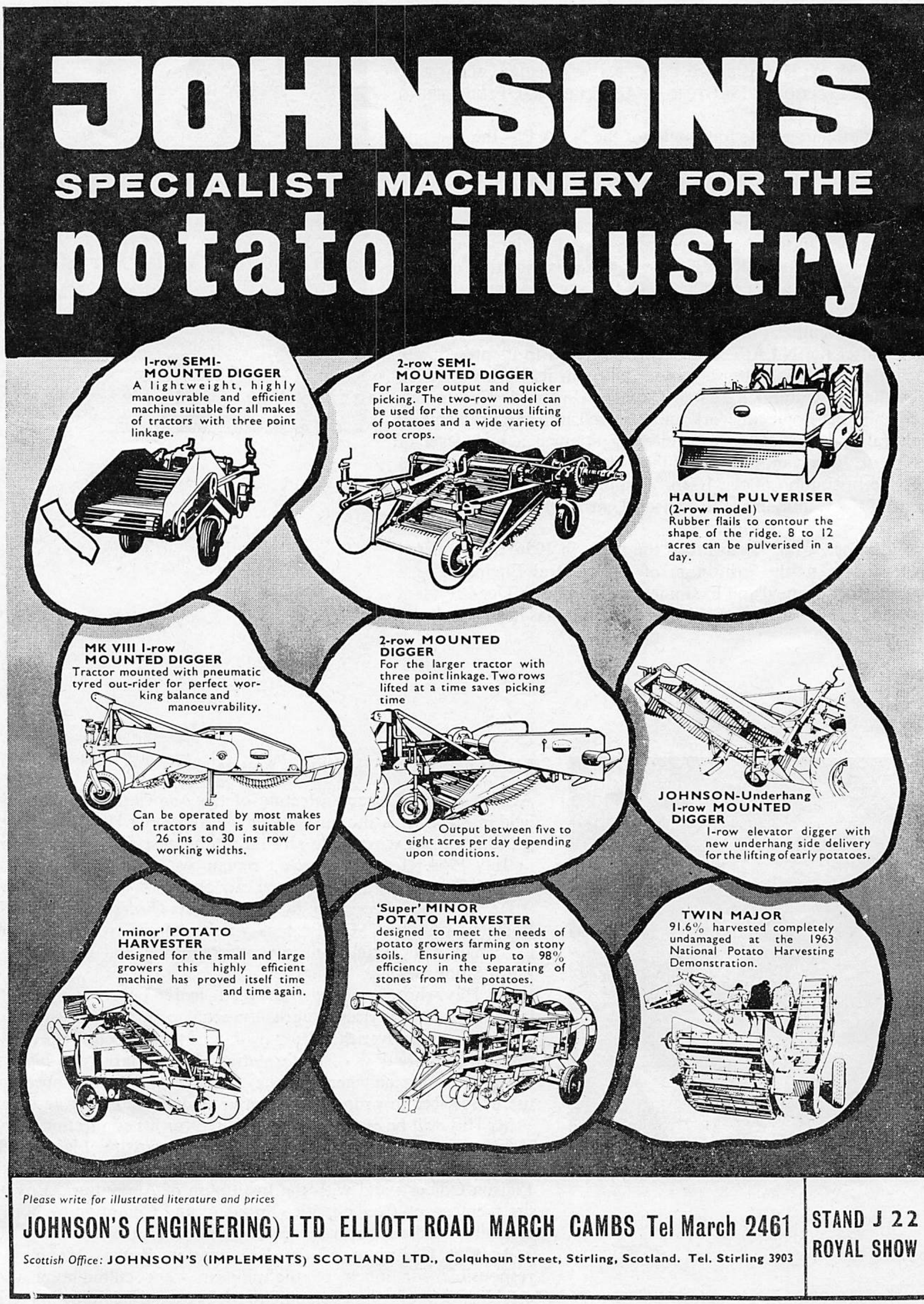
At the Annual General Meeting of the Association of Agriculture held in May it was announced that Mr Alexander Hay, O.B.E., N.D.A., N.D.D., HON.M.I.AGR.E. is to retire from the post of General Secretary in July 1964. He will, however, remain with the Association as its Special Consultant in a part-time capacity.

He will be succeeded by the Deputy Secretary, Miss Joan Bostock, A.I.AGR.E. Miss Bostock was appointed to the Association in 1952 for the prime purpose of organising and developing the Farm Study Scheme.

Mr Hay who was awarded the O.B.E. in 1963 in recognition of his long and varied services to agriculture and to agricultural engineering education, took over the Secretaryship of the Association in 1948 in the critical early days of its formation. Thanks largely to his knowledge and able management, the Association has developed many useful services in promoting a better understanding of agriculture.

Mr Hay will be especially remembered for his connection with the Department of Agriculture for Scotland (as war-time Liaison Officer for Roxburghshire); with the BBC (as Deputy to the Agricultural Liaison Officer); and with the Institution of Agricultural Engineers (as member of Council, Vice-President and Chairman of both the Examination Board and the Education Committee).

As first Chairman of the Examination Board, Mr Hay was responsible for much of the pioneer work culminating in the establishment of courses leading to the National Diploma in Agricultural Engineering.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SPEECHES AT THE ANNUAL DINNER OF THE INSTITUTION

28th April 1964

MR J. D. F. GREEN, M.A., (Chairman of the Agricultural Advisory Council for England and Wales), proposing the Toast of 'The Institution of Agricultural Engineers' recalled how Lieutenant-Colonel Philip Johnson, Mr Alexander Hay and Dr Cornelius Davies met in his office at the B.B.C. during the latter part of the War. Their discussions at that time had proved to be an accurate forecast of the Institution's development but they could scarcely have perceived the extent of the revolution which was to take place. Britain emerged from the Second World War with a potential lead in agricultural engineering that the ensuing ten years was to see consummated. Nothing like it had emerged from the First World War. It was true, continued Mr Green, that this nation drew level with the Germans in the development of certain neglected industries, such as optical glass but we had never previously established a major industry literally from nothing. In 1916 Britain produced the tank which played its part on the Somme and yet in 1939 she commenced the Second World War without any native earth-moving equipment and with only one make of track-laying tractor. It was incredible that between the Wars Britain should have been content to regard farm mechanisation as the prerogative of the North American Prairies. We had a reputation in marine and mining engineering that dated back to the last century; however, when it came to land this was thought not to be our concern. It was, therefore, most significant that in 1963 British wheeled agricultural tractor production exceeded that of the United States of America. This was an example of how the natural protection afforded by War could help an industry get on its feet.

Mr Green said he did not want to talk politics and, in a party sense, he would not do so. However, he could

The Institution's Annual Dinner 1964

(Acknowledgements to Belgrave Press Bureau)

Pictured above (left to right) are Mr W. P. Authers, President of the Agricultural Engineers Association, Mr W. J. Priest, M.I.AGR.E., President of the Institution and Mr J. D. Green, M.A., Chairman of the Agricultural Advisory Council for England and Wales, on the occasion of the Institution's Annual Dinner at St Ermin's Hotel, London, on 28th April 1964.

A telegram of greetings and good wishes was sent from the assembled gathering to the Founder President of the Institution, Lt.-Col. Philip Johnson, C.B.E., D.S.O., M.I.MECH.E., HON.M.I.AGR.E.

not understand the senseless argument about the icy blast of competition being so good for man. It was a shibboleth that young politicians seemed to learn from old Treasury officials who are unable to forget Mr Gladstone. The Safeguarding Acts had helped to make the motor industry and the Second World War had now given this country world leadership in the field of agricultural engineering. A jaundiced view of human nature could lead to the assumption that man was so indolent by nature that he would never grasp his opportunities if left to his own devices. If agricultural machinery manufacturers were today 'having it good' they owed it to their own initiative when they were presented with a home market for the first time. Today, that market was the basis from which a world-wide sales organisation sprang. Mr Green said that as Chairman of the Agricultural Advisory Council he had one special message. Our achievements with power units and crop mechanisation might be commendable, but he insisted that the task for the future lay in the mechanisation of livestock. The animal could not be sheeted down from Friday to Monday. As overtime rates increased, so would stock husbandry disappear, if engineers were not able to move the bulk that built up at both ends of the animal. It was perhaps a misfortune that the animal utilised so little of the bulk it was given, whilst on the other hand it voided so much. Here then, was the new challenge which should take the form of automatic feeding and removal of effluent.

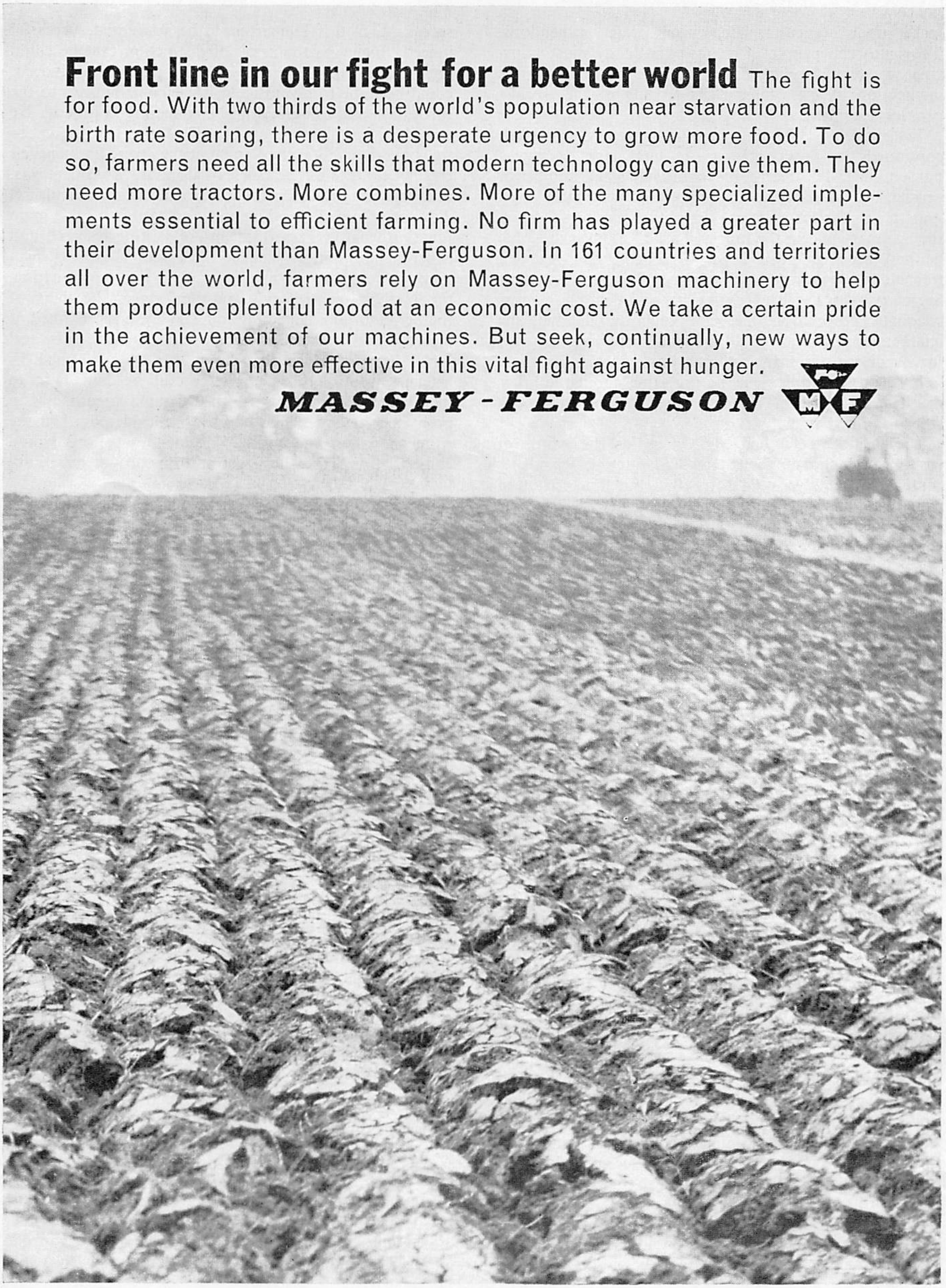
Responding to the Toast, Mr W. J. Priest, M.I.AGR.E., President of the Institution referred to the fact that the Institution had at its Annual General Meeting earlier that day shown itself willing to re-elect him for a second Presidential year. He gave assurance of his deep sensibility of that honour and hoped he would be allowed to state publicly that he was also grateful to the directors of his Company for permitting him to spend some of his time—and consequently some of his employers' money—on Institution affairs. He added that he was more than grateful to those members of his staff upon whom extra work so often fell during his Presidential peregrinations.

Mr Priest recalled that at the previous Annual Dinner he had made reference to that well-worn saying that 'the first twenty-five years in the existence of any organisation were reckoned to be the worst!' The Institution's 25th year had just come to its end; it had been a year of tribulation and of triumph. Triumph, because despite the great loss sustained so soon after the year began there had been no deviation from the progress towards the greater achievements to which we were pledged. We had not merely talked about raising the qualifying standards for membership; much painstaking and detailed work had gone into the formulation of plans to bring that about by stages over the next 20 years. These plans, like all the others which the Institution put into operation, were designed to bring about the more effective application of engineering to agriculture. It became more evident every day that successful agriculture all over the world was tending to be more and more dependent upon efficient engineering.

The President said he believed that all engineers, and especially all agricultural engineers, were anxious that their work should be done in such a way as to be of benefit to the community. They must be dedicated to a life of service and service—as Mr W. P. Authers had said recently in another place—is 'a massive and meaningful matter'. That was why the Institution was so intimately concerned with education in agricultural engineering—a matter that was still not always accorded as much careful attention in some places as it ought to be. Agricultural engineering education had a somewhat tortuous pathway to pursue and it was essential that the various bodies involved in the matter would be able to co-operate and not conflict with each other. Mr Priest said that in this respect he thought the Institution could play and indeed was playing a valuable role. He gave an assurance that the Institution's concern with this country's agricultural engineering education facilities should be such that all the way up the ladder we should be able to turn out the best agricultural engineers in the world. There was no reason on earth why that should not be possible.

Mr Priest confessed himself surprised that in this latter half of the 20th century it seemed not always to be clearly understood that agricultural engineering had attained great stature. There were still far too many people who appeared to think that agricultural engineering consisted of making and selling some odd looking machines and implements in order that farmers could leave them out in the fields to rust! The President said that whilst he knew he ought to be the last to say so, in his view public relations were in this respect not nearly as good as they ought to be. He added that he was quite certain that all the member firms large and small of the A.E.A. and the members of the A.M.T.D.A.,—representatives of which two bodies the Institution so gladly welcomed there that evening,—would cordially agree with him that fully trained and well qualified staff were essential in their various businesses. Machinery manufacturers could not function without engineering skill of a high order and machinery distributors, who must always be competent to provide first-class service, were bound to see to it today more than ever before that their engineering standard was high.

Mr Priest continued that in making all these observations he was not unmindful of the function of that Council over which Mr Green presided. Its task, as he understood it, was to promote the transmission of new ideas and to strengthen the links between research and the farmer. The Institution had a hand in this kind of operation also. All this, the President went on, might seem to be 'rather dry stuff' to put out on a social occasion but he admitted to being unrepentant on this occasion. We lived in a day when giant corporations in business and in many other spheres of life were mighty fashionable. It was sometimes suggested that one immense engineering institution would best serve the needs of the country and the world—a giant body within which specialised groups could function. The President said this might perhaps be so, but he could assure his listeners he was in no sense converted to the idea. There was undoubtedly a place for the smaller professional institution such as this and one should not take too much notice of the term 'smaller' for our own Corporate Membership continued to grow. The demands


Front line in our fight for a better world The fight is for food. With two thirds of the world's population near starvation and the birth rate soaring, there is a desperate urgency to grow more food. To do so, farmers need all the skills that modern technology can give them. They need more tractors. More combines. More of the many specialized implements essential to efficient farming. No firm has played a greater part in their development than Massey-Ferguson. In 161 countries and territories all over the world, farmers rely on Massey-Ferguson machinery to help them produce plentiful food at an economic cost. We take a certain pride in the achievement of our machines. But seek, continually, new ways to make them even more effective in this vital fight against hunger.
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made upon agricultural engineers were tremendous. They must be people of many parts; they must know what modern farming involved and on the sensible application of their talents the feeding of the world's peoples depended.

The work of maintaining an Institution of this kind, continued the President, was no light task. It was a burden which fell upon a comparatively small number of people and to them all the Institution was more than grateful. By far the greatest part of that burden fell upon the Secretary and in the four and a half months in which he had been in office Mr Jon Bennett had revealed tremendous capacity and ability. To the Assistant Secretary, Miss Pamela Housley, it was difficult to express adequate appreciation. The remarkable way in which she had kept the Institution's affairs so efficiently ticking over for six difficult months last year was a model for all to follow. One could say exactly the same about the other members of the staff. To their enthusiasm and energy the Institution owed much.

The President thanked Mr Green for the words of wisdom and encouragement he had uttered. Presidents come, Presidents go, said Mr Priest, but the Institution would continue to labour mightily for the further advancement of the greatest technology in the world—agricultural engineering.

The President said he hoped he might be allowed to end his remarks as he had begun—on a slightly personal note. He was proud to set out upon another year, though still wondering why this honour had been accorded him. Nevertheless, he had drawn consolation from lines which he had discovered a few days previously and which he believed was called 'a modern poem':—

An editor knocked at the Pearly Gates,
His face was scarred and cold;
He stood before the man of fate
For admission to the fold.
'What have you done,' St Peter asked,
'To gain admission here?'
'I've been an editor, sir,' he said
'For many and many a year.'
St Peter's eyes were warm and kind
With just a tinge of mirth,
'Come in,' he said, 'and choose your harp,
'You've had your share on earth.'

The President closed by assuring his listeners that his small share in the work of this Institution was something which he treasured highly.

Mr J. H. W. Wilder, B.A., M.I.AGR.E., Vice-President and President-Elect of the Institution proposed the Toast to the Guests. Referring to the excellence of the two previous speeches he confessed to feeling conscious of the dangers of public speaking and promised to remember the advice given by Mother Whale to her off-spring: 'Don't spout—it's only when you do so that you are likely to get harpooned!'

Any gathering of this kind, said Mr Wilder, was made worthwhile by the presence of its guests. If the quality and the number of guests were to be the yardstick of success, then this Dinner could be accounted successful indeed. Such was the array of distinction that he could not possibly mention everyone by name; nor indeed, could he hope to do justice to their contributions to the Institution and to agricultural engineering in general. He was, however, happy, on behalf of the Institution, to welcome them all in the hope that they were finding their evening enjoyable. The Guest of Honour, Mr Green, was, as everybody present knew, Chairman of the Agricultural Advisory Council for England and Wales, whose main function was the important one of visiting research and experimental stations and colleges with a view to promoting the transmission of new ideas and to strengthen the links between research and the farmer. The giants of the agricultural engineering industry were represented at director level by Mr Batty of Ford Motor Company and Dr Willetts of Massey-Ferguson. Mr Wilder hoped his listeners would observe how careful he had been to mention both these firms in the same breath. When preparing his speech he had even considered which he should mention first and had decided that Ford would come first as 'True Blue' was still on top—at least until October!

The Institution had many benefactors firms which gave donations or became affiliated organisations or financed scholarships. Mr Wilder said that the presence of Mr Mott of Shell-Mex and B.P. gave the opportunity of thanking all the Institution's benefactors, including Mr Mott's firm for their invaluable support. The Press were welcome at these gatherings. He had always thought and he believed that many shared his view, that the Press coverage of the industry was worthy of great respect, a fact which was reflected by the Institution's selection of its current President. Mr Hudson, Director of Morgan Brothers and Mr George Wardrop, General Manager of Farmer & Stockbreeder, both of whom were present, had earned the Institution's indebtedness for the assistance which their publications had most generously given. Mr Wilder also welcomed the presence of Sir John Winnifrith, Permanent Secretary to the Ministry of Agriculture, Fisheries and Food and Mr J. Williams, Head of the Steel Users Section of the British Iron and Steel Research Association.

This Institution, Mr Wilder continued, had treated education as being its main priority. Not all schoolmasters had shown themselves interested in modern technical developments, as in the case of one schoolmaster in particular who prided himself of being 'with it' and took a special interest in computers. At a demonstration of this equipment he put the question to the computer 'will it be wet or fine tomorrow?' After considerable thought the computer came up with the answer 'Yes'. 'Yes—what?' asked the schoolmaster. After much hesitation and internal activity, the computer somewhat reluctantly produced the reply 'Yes—Sir!'

The National College of Agricultural Engineering was, Mr Wilder believed, the brain child of the Institution and it was pleasing to see bricks and mortar rising on the Silsoe campus, a dream turning into reality. Mr Wilder welcomed to the gathering Sir Gilbert Flemming, Chairman of the Governing Body of the College and wished him well. Mr Christopher Dadd, Technical Director and Secretary of the Royal Agricultural Society of England and who was a Companion of the Institution was faced with the challenging task of re-defining the R.A.S.E.'s motto 'Practice with Science' in the environment of the second half of the 20th century. His presence as a guest this evening and his membership of the Institution led one to hope that he recognised the part that the agricultural engineer could play in this task. The President-Elect then referred to Mr W. H. Cashmore and pointed out that this would be the last occasion that he would attend an Institution Dinner in his capacity as Director of the N.I.A.E. That Institute had sometimes been the centre of controversy and of political pressures. Its precise rule had been, still was and probably would always remain the subject of discussion, but, said Mr Wilder, however much the winds might blow, he had never heard anything but praise for the standing and integrity of the Institute. He believed this extraordinary high reputation, both national and international, could be directly attributed to Mr Cashmore who had done a great job and was held in much affection and respect. The good wishes of the Institution for Mr Cashmore's health and good fortune would accompany him on the eve of his retirement. Mr Moss, who would succeed Mr Cashmore was also present. Being new to agricultural engineering but not, one could rest assured to other fields of engineering and research, Mr Moss no doubt listened with interest to the salutary tale of that distinguished engineer having no connection with agriculture or agricultural engineering who suffered a nervous breakdown and was sent to the country to convalesce. Eventually he recovered sufficiently to take a walk in the country. On seeing a machine at work in a field he went across to study it; as soon as he could see the details of this example of the agricultural engineer's art, he promptly suffered a second breakdown. Mr Wilder rejoined that he had the good fortune to have gained Mr Moss's acquaintance during recent weeks and he believed that far from being in danger of a nervous breakdown, Mr Moss would bring an able and penetrating mind to bear on the industry's problems.

Mr Wilder then sought leave to quote a remark attributed to Lady Godiva at the end of her famous journey: 'I am nearing my clothes'. The A.E.A. and the A.M.T.D.A. were represented by the Presidents and Secretaries of both Associations. Mr Ben Burgess the hard hitting and almost tycoon-like President of the A.M.T.D.A. was a member of the Institution and indeed had been a past member of the Council and a past Branch Chairman. There was thus no doubt that the honour bestowed on him when elected President of A.M.T.D.A. reflected some glory upon this Institution.

Mr Authers, newly elected President of the A.E.A. had brought great pleasure by his attendance as a guest this evening following so soon after his election. His hard work for many years in the interests of the A.E.A. was well known. His many friends in the industry were delighted that his work had culminated in the election to his high office and the Institution would wish him well in the year ahead. Mr Wilder then closed by formally proposing the Toast to the Guests and coupled with it the name of Mr Authers.

Responding to the Toast of 'The Guests' Mr W. P. Authers, President of the Agricultural Engineers Association said he greatly appreciated the opportunity of being one of the Guests. He could speak for them all in saying how much he had enjoyed the Institution's hospitality, not only for food, but also for the friendly welcome and the congenial atmosphere which had made all the Guests feel very much at home.

Mr Authers said this occasion gave him particular pleasure because both the President and the President-Elect of the Institution were old friends of his. Indeed, Mr Priest was the friend of all engaged in this industry. 'His knowledge of us and of our businesses is uncannily comprehensive', said Mr Authers, 'and we are grateful to him for keeping quiet about it.' The Presidential address which Mr Priest had given the previous October had been fitting and felicitous, marking the Institution's 25th milestone with its keynote 'Achievement and Anticipation'. Mr Authers said he had been particularly interested in the remarks in that address on 'the ploughwrights and hedge-side carpenters' who were the fore-runners of the agricultural engineers of today. When he had been collating evidence for the Transport Tribunal a few years previously it had been remarkable how many of the well known and substantial firms in the industry had sprung from the invention of some implement or device, often by the village blacksmith who had been closely in touch with the farming needs of his locality. Mr Authers quoted his own Company as one example. Tradition had it that the first Mr Twose had been the village blacksmith (acting as village undertaker as a sideline). He had invented an implement which he had pushed all the way from Halberton to South Molton market, a matter of some 20 miles on roads which nowadays would be classed as 'B' roads and in 1930 that description was even more appropriate. The inventor had failed to sell his machine and had pushed it the 20 miles back again. Unfortunately—or perhaps fortunately—his comments had not been recorded for posterity.

Recalling a remark he had made in a speech the previous week to the effect that the success of the industry was based on sound technical development, Mr Authers said he welcomed on behalf of his fellow guests and himself this opportunity to underline the importance of the Institution which had come into being because this need for sounder technical development had been recognised. In giving form and status to the professional qualifications the Institution had added stature to the industry. In the great partnership called agriculture the Institution held a key position in helping to ensure that the contribution of the agricultural engineers of this country was a worthy one. In this work there was a close association with the National Institute of Agricultural Engineering, whose director, Mr Cashmore, had well earned all the tributes and gratitude that would continue to be expressed in the period until his retirement in July. Everybody would look forward to a continuation of that relationship when Mr Moss took over.

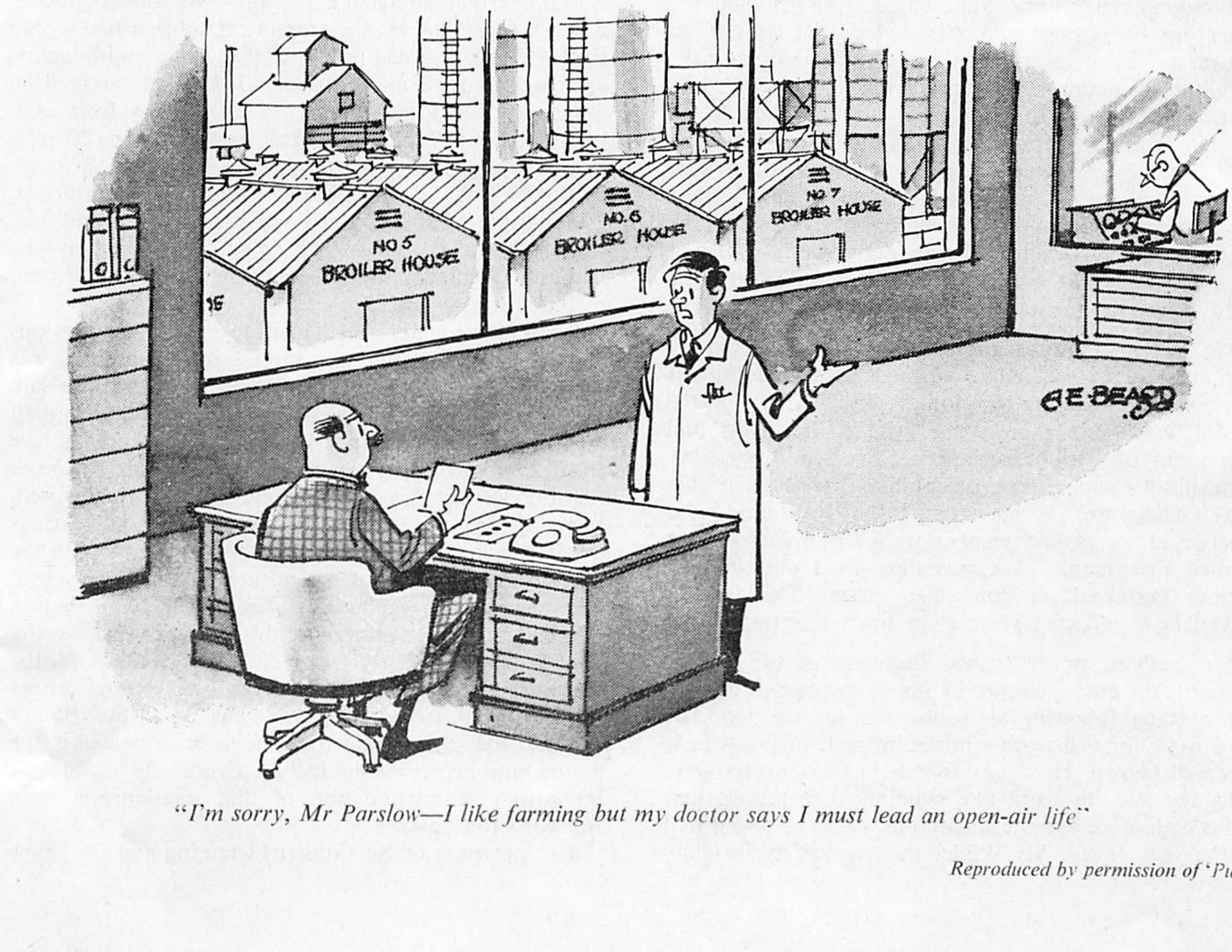
The presence of Sir Gilbert Flemming and Dr Payne among those present enabled Mr Authers to express once again the good wishes of the A.E.A. to the National College—this young but lusty neighbour of the National Institute. He and his colleagues in the A.E.A. had followed the emergence of the College with interest and with, he hoped, practical sympathy. If ever there was a risk of his Council meeting finishing within a reasonable time the Chief Executive invariably placed on the Agenda 'design of Gold Medal for National College.' So eager was the Association that this award should be suitable that his Council could happily spin out any meeting at which it was discussed. Some day, said Mr Authers, someone would actually receive the A.E.A. medal and the monetary award that would go with it.

The Agricultural Engineers Association had in the previous week issued statistics showing that no less than eight records of production and experience had been broken in 1963. Members of the Institution could share in this sense of achievement and would be the first to endorse his contention that if this nation could export some two-thirds of its output there could be nothing much wrong with the design and workmanship in British tractors and farm machinery. Such a statement was in itself a spur to further efforts. To maintain this position the country needed technical ability of the highest order. The nature of the work and the nature of the men engaged in it made them restless and unremitting in their research. The Institution sustained and sharpened their efforts.

Mr Authers closed by extending on behalf of all the guests best wishes to the Institution for its continued success and added an assurance that in its endeavours the Institution could rely upon the full and friendly support of the A.E.A.

ROYAL SHOW, KENILWORTH

The Secretary and Assistant Secretary will attend the Show on Tuesday and Wednesday, 7/8 July 1964, and will be available on Stand No. 25, Avenue E (*Farm Implement and Machinery Review*) through the courtesy of Messrs. Morgan Brothers (Publishers) Ltd., and the Editor, Mr W. J. Priest, M.I.AGR.E.



"I'm sorry, Mr Parslow—I like farming but my doctor says I must lead an open-air life"

Reproduced by permission of 'Punch'

OBITUARY

Council records with deep regret the death in March 1964 of Mr Harold Ormerod Stainton Pilkington, M.I.AGR.E. at the age of 72. After spending several years farming, in 1928 he joined Bomford & Evershed Ltd to take charge of the dredging department. In 1938 he became Managing Director of the Company, which post he held until his retirement in 1956. Mr Pilkington was a prominent member of the West Midlands Branch of the Institution.

LETTER TO THE EDITOR

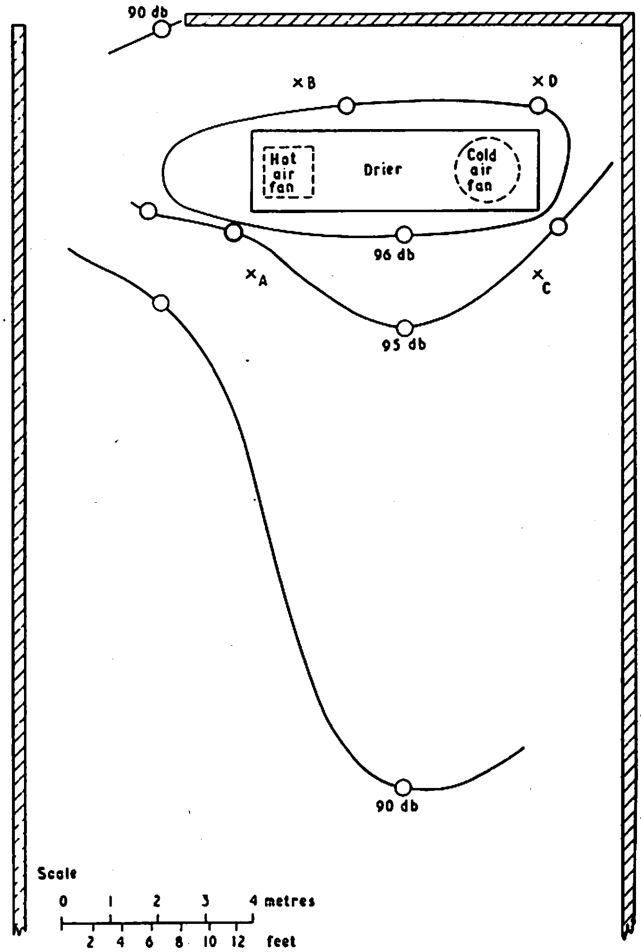
Dear Sir,

With reference to the report of the discussion on Mr S. W. R. Cox's paper 'Noise Measurement and Analysis', Vol. 20, No. 1, p. 63: in my contribution, 'Isobels' are not the units of contours of equal sound pressure level but the contours themselves, by analogy with isobars, etc. The relevant units of the 'Isobels' have so far been db, but could be dbA. I enclose a diagram from a recently published test report to illustrate the point, and am sorry if I did not make it clear at the meeting.

Yours faithfully,

P. H. BAILEY

Head of Drier Performance Department
National Institute of Agricultural Engineering,
Silsoe, Bedford.



THEORY AND PRACTICE OF OFF-THE-ROAD LOCOMOTION

by A. R. REECE, B.SC.(MECH.ENG.), M.SC.(AGR.ENG.), A.M.I.MECH.E., A.M.I.AGR.E.*

Presented at the Annual Conference, London on 28th April 1964

The use of off-the-road vehicles is by no means confined to farming and the other uses are growing at an increasing rate. The earthmoving business has become very large and important, and the processes involved have much in common with those of agriculture. Cross-country transport for exploration and exploitation of mineral resources and for the servicing of public utilities such as power lines, pipe lines and radar stations is a rapidly growing field. Timber extraction and transport are beginning to demand specialized vehicles. Developments in military technology are demanding even greater emphasis on mobility and a widening range of logistic and fighting vehicles for more and more difficult terrain is being produced. Vehicles for sports such as ski-ing and hunting are beginning to make a useful market and in commercial terms one cannot neglect contracts that have been recently placed for the development of lunar vehicles and lunar moving equipment.

There is little doubt that agriculture forms the biggest single market for off-the-road machinery and therefore the farm machinery industry is fairly well placed to obtain a share of these other markets. For this reason and because the basic problems of a tractor and any other cross-country machine are the same, it would be foolish not to consider the whole field as one subject. It seems, therefore, that the whole of off-the-road locomotion should be within the field of interest of such bodies as The Institution of Agricultural Engineers and a University Department of Agricultural Engineering.

With the developing production of a widening range of off-the-road vehicles has come a greater interest in the theoretical study of the principles involved. It is a study which has no generally accepted name but which perhaps may come to be called *terramechanics*. The aim of this theory is better vehicle design through a detailed quantitative understanding of the factors involved. These can be divided into four groups. The first is soft ground performance – undoubtedly the major problem – the study of which is now called soil vehicle mechanics. The second problem is concerned with the crossing and negotiation of obstacles such as trees, rocks and ditches. The third problem is concerned with vehicle vibration and particularly the achievement of smooth ride at high speed over randomly rough surfaces. The fourth problem is concerned with the water performance of amphibians and the particularly difficult transition phase between water and land.

The whole problem of terramechanics can be viewed from another standpoint. The situation often arises in which a particular fleet of vehicles is available to do a certain job in a specified territory and the problem then is to decide what load the vehicles can carry, what path they should follow and how fast they can be expected to travel. This is a problem of particular interest to military authorities who may well have to make these decisions without having access to the territory involved. The study of this aspect of terramechanics is described by the terms *trafficability studies* and *terrain evaluation.*

Many will object to the creation of this new field of technology, contending that all successful cross-country machines are produced by practical men and not by scientists. These critics will maintain that one has only to think of such men as Cuthbertson, Johnson and Nodwell to see the truth of this. They will go on to say that soil is so complex and variable in its properties that it defies numerical treatment, its comprehension requiring years of experience coupled with that type of subconscious judgement and wisdom that is needed in much of business life. These critics may go on to say that here we have yet another example of the creation of expensive and unnecessary jobs at public expense.

There are many reasons why this point of view is incorrect. The facts are that new developments are increasing the result of the work of the theoreticians. Just as aircraft were built originally by practical men like the Wright Brothers but are now the product of large teams of scientists, so it is with vehicles. To take but two examples, the whole contemporary development of the articulated tracklaying vehicle definitely stems from the work of Bekker and Nuttall who saw that this was the only way out of the severe limitations imposed by the mechanics of skid steering.[1] A rather different case is the Gama Goat, a vehicle whose form originated in the mind of a practical man but whose actual proportions owe a great deal to the calculations of the Land Locomotion Laboratory and the Vought aircraft designers.[2] It is not true that soil is too complex to understand. Already, as the writer hopes to show, we have theories sufficiently accurate to give a very considerable understanding. A third reason can be found in the development of modern, large-scale organizations depending on committee decisions. It is often the case that the right practical man is not on the committee and mistakes can only be prevented by a formalized design and evaluation processes that do

* *Lecturer in Agricultural Engineering, University of Newcastle.*

not depend upon personal power. A fourth reason arises when vehicles have to be designed for unfamiliar environments of which, of course, the most exciting are those to be found in space. Already multi-million dollar contracts are being carried out for the development of lunar vehicles and moon moving machinery. This raises questions such as 'To what extent is the supporting capacity of a dry sand dependent upon the pull of gravity on the sand itself?'

To the writer however, the most important reason for the study of soil vehicle mechanics is an educational one. The training of agricultural engineers at University level is a relatively new enterprise which aims at producing creative engineers in a shorter overall period than the old method of practical experience alone. In order to achieve this the University must concentrate upon the teaching of principles and the scientific method applied to each particular field. The young engineer must then add to this some years of experience of the application of these principles and must support them with an adequate background knowledge. There is no alternative to this approach; attempts to transmit the practical man's wisdom directly always fail. If the scientific approach is the aim of academic agricultural engineering, then it is plain that the principles of soil-vehicle (and soil-implement) mechanics must form an important part of the teaching. Unfortunately in this, as in most other branches of agricultural engineering, the principles are obscure and can only be taught after considerable research on the part of the teacher. The research effort in the field of soil-vehicle mechanics at the University of Newcastle is therefore not aimed at the direct improvement of the farm tractor but rather at the elucidation of principles which can be taught to students who will subsequently use them in the development of better machines.

The soft ground performance of vehicles is the most difficult of the problems of terramechanics and the one of greatest interest to agricultural engineers. The author would define the objective of soil vehicle mechanics as the quantitative understanding of the performance of simple vehicles in deep uniform soils. This would provide guiding principles for more rational evaluation and test methods, and an intellectual framework into which field experiments could be fitted to make a comprehensible picture. This is a much more limited objective than has been aimed at by others in this field but it is possibly more realistic. There are only two real sources of inspiration in the study of soil-vehicle mechanics. Historically, the first is British, being the work of military scientists at The Fighting Vehicle Research and Development Establishment (F.V.R.D.E.) and its preceding organizations. Micklethwaite, Evans, Sherratt and, to-day, Uffelman have produced a simple and elegant theory for tracked and wheeled vehicles in frictionless, saturated clays (conditions which have caused the most serious mobility problems for the military).[3, 4] These theories have been verified by adequate experiments and constitute a considerable scientific achievement.

The second source of inspiration is in the work of Bekker and his associates at the Land Locomotion Laboratory.[5, 6] They have formalized the total problem and done a great deal to interest others and stimulate work in the field. In soil-vehicle mechanics they have attempted to advance on the British work by constructing a theoretical system applicable to all soils. They have constructed a general and quite simple system but have not so far supported it with much experimental evidence. The work of these two groups can therefore be summed up as providing an effective scientific theory for clay soils and a very useful hypothesis for all uniform soils. At the University of Newcastle work in this field was started about five years ago and the first efforts were concerned with an evaluation of the Land Locomotion Laboratory theory in sandy soils.[7, 8] Sufficient work has now been done, to suggest we can begin to make a contribution to the further development of soil vehicle mechanics.

The prediction of traction and slip is common to both the Bekker and British systems. Maximum thrust from a vehicle is proportional to the soil shear strength described by Coulomb's equation

$$s_{max.} = c + p \tan \phi \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad 1$$

The development shear stress with slip is described by the simple exponential relationship

$$s = s_{max.} \left(1 - e^{-\frac{j}{k}}\right) \quad \ldots \quad \ldots \quad \ldots \quad 2$$

These two equations can be simply applied to any drive element with a flat contact area to give an expression for the gross horizontal thrust H, as a function of slip i.

$$H = (ac + W \tan \phi)\left(1 + \frac{k}{il} e^{-\frac{il}{k}} - \frac{k}{il}\right) \quad \ldots \quad 3$$

Our experience at Newcastle has been that these equations work well if the vehicle sinkage is not too great. We can with some confidence use these equations and a typical problem that out students are asked to work out is to compare the respective performances of an ordinary tractor, its four-wheel drive conversion and a full tracked version on a typical farm soil. The properties of British agricultural soils have been described by Payne and Fountaine and Fig. 1 is reproduced from their N.I.A.E. Technical Memorandum 116. The most common soil properties are a value of ϕ of $34\frac{1}{2}°$ and a cohesion of $1\frac{1}{2}$ lb in^{-2}. We have found that for frictional soils, k is about 1 (this means that 95 per cent of full shear strength is developed at 3 in of shearing movement). The details of this problem are shown in Fig. 2 together with the calculated pull/slip curves. Also shown in the figure are the pull/slip curves from the N.I.A.E. Test Reports of the three tractors concerned, operated on dry cultivated loam. The computed results are obviously on the right lines and this theoretical exercise makes quite clear the differences in the characteristics of the three types of tractor. The four-wheel drive makes use of all of the tractor weight and a little more use of the soil cohesion and has the same high slip characteristics as the two-

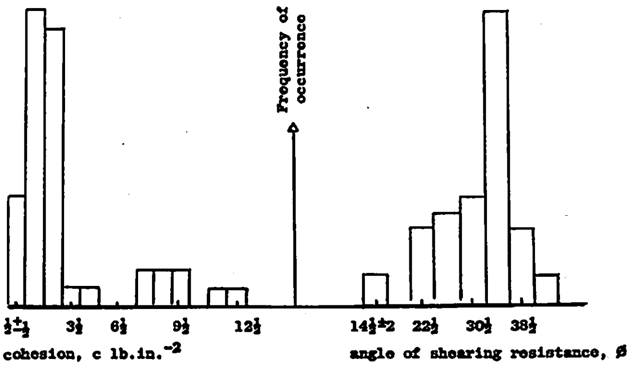


FIG. 1
The frequency of occurrence of various values of c and ø in British agricultural top soils. (From N.I.A.E. Technical Memorandum No. 116 by P. C. J. Payne and E. R. Fountaine).

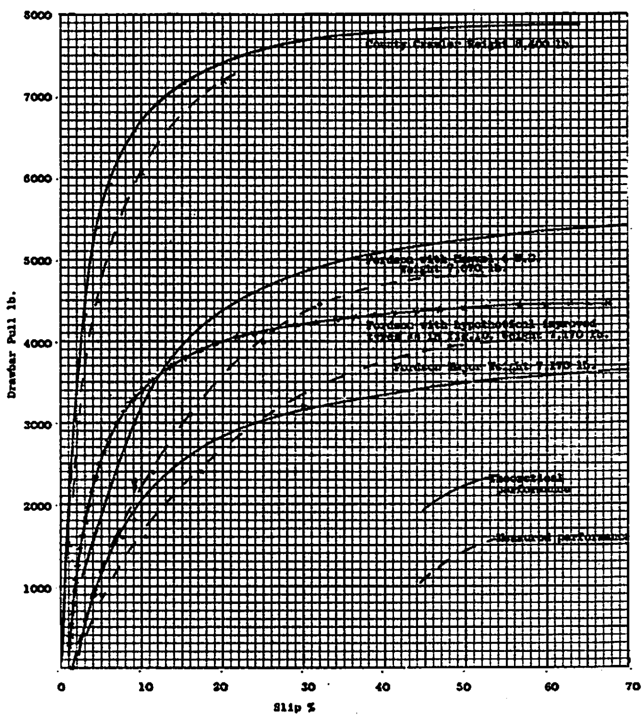


FIG. 2
An example of the use of equation 3 to predict the performance of three types of tractor. Assuming the properties of cultivated loam to be $\phi=34\frac{1}{2}°$, $c=1\frac{1}{2}$ lb in^{-2}, $k=1$. Tractor weights and dimensions from N.I.A.E. Test Reports 88 and 134. Drawbar height 14 in. Length of tyre contact patch 22 in. Rolling resistance assumed 500 lb tracklayer, 750 lb wheeled tractors.

wheel drive. The crawler makes even more use of cohesion and also develops a high drawbar pull with very low slip due to its long contact length. Shear of agricultural soil is often a harmful process because of puddling and compaction and it is interesting to note that with a drawbar pull of 3000 lb. the two wheel drive shears the soil under its wheels to a distance of 4 in, the four-wheel drive 3.4 in and the crawler only 1.3 in.

The exercise involved in making this computation is probably as valuable in the instances where it does not fit the experimental results as in those where it does. The calculations for the four-wheel drive assumed that the front and rear wheels were running on undisturbed soil, while in fact the rear wheels ran in the ruts of the front wheels. This seems to give rise to a considerable overestimation of performance, and speculation about the reasons for this should suggest interesting future research topics.

Both the British and Bekker theories calculate rolling resistance from the work done in making the rut, using a pressure sinkage relation obtained from the sinkage of flat plates. The British equation for frictionless clay is simply

$$p=kc \quad \ldots \quad 4$$

and the general Bekker equation is

$$p=\left(\frac{k_c}{b}+k_\phi\right)(z)^n \quad \ldots \quad 5$$

Equation 5 is not acceptable for the following reasons:

(*a*) it does not fit experimental results at all well;
(*b*) it cannot accommodate equation 4 as a special case;
(*c*) it conflicts with bearing capacity theory;
(*d*) it is not dimensionally acceptable because k_c and k_ϕ do not have constant dimensions;
(*e*) it is purely empirical and there is no way of calculating k_c, k_ϕ or n.

Recent work by the writer has led to the proposal that in general:

$$p=f\left(\frac{z}{b}\right) \quad \ldots \quad 6$$

and if one likes the form $p=kz^n$, then

$$p=\left(ck_c'+\gamma\frac{b'}{2}k_\phi'\right)\left(\frac{z}{b}\right) \quad \ldots \quad 7$$

This overcomes neatly all five objections, simplifying to equation 4 in the simple case when $k_\phi=O$ and $n=O$.

Equation 7 will give quite reasonable results when applied to predicting the rolling resistance of towed rigid wheels in uniform soils and it is clear that the principle that the work expended on rolling resistance equals the work involved in making a rut is on the right lines. Typical results of a regular teaching experiment carried out by our students using the apparatus shown in Fig. 3 are shown in Fig. 4. Our rolling resistance research has shown that the Bekker theory for towed rigid wheels underestimates because it neglects the fact that some work is also expended on deforming the soil horizontally and overestimates due to the use of certain mathematical simplifications. Sometimes these two factors cancel each other out but the theory can in general give either a low or high answer. We hope to publish an improved theory before very long.

Both Bekker and the F.V.R.D.E. assume that the drawbar pull of a vehicle is equal to the difference between its gross thrust and its rolling resistance described by

$$D=H-R \quad \ldots \quad 8$$

In this equation H is calculated from equation 3 and R from equation 7 and H and R are independent of each

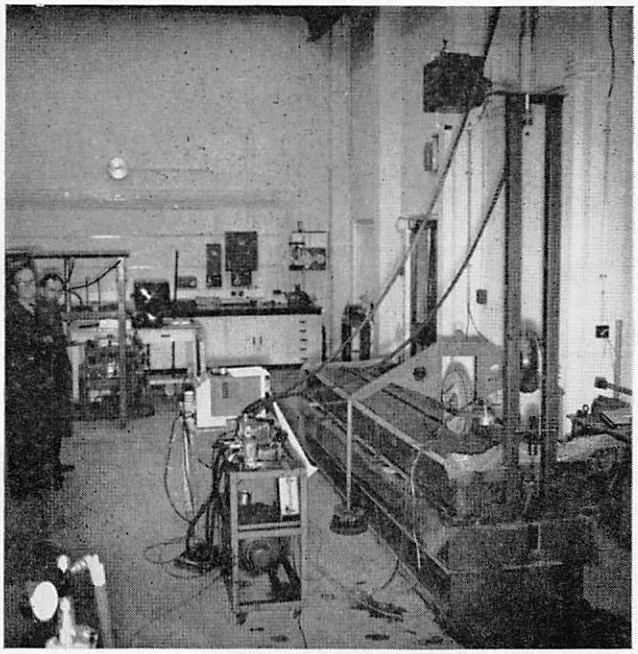


FIG. 3
Apparatus used for measurement of rolling resistance of small towed wheels in controlled soil conditions in the laboratory. The wheel is hauled by a variable-speed hydraulic ram and rolling resistance and rim pressure are recorded from strain gauge transducers.

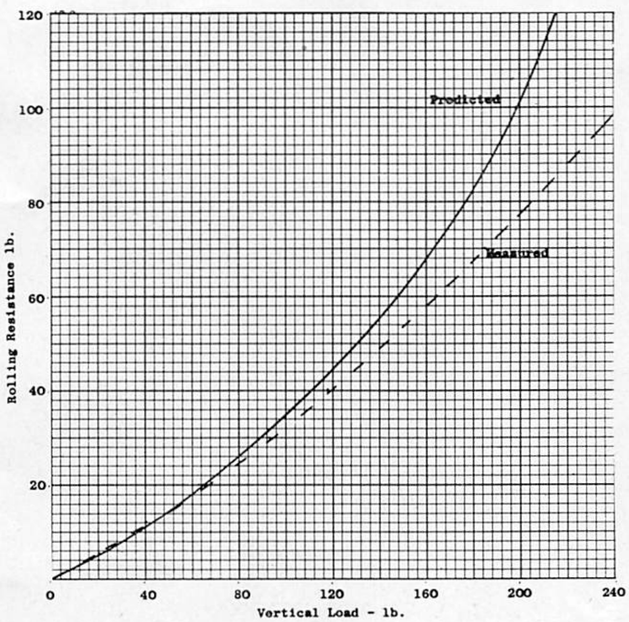


FIG. 4
Typical example of the relation between predicted and measured rolling resistance. Calculated values from Bekker's equation for rigid wheels.[6] Experimental values obtained from the apparatus shown in Fig. 3 using a 20 in dia. wheel, $1\frac{1}{2}$ in wide in damp sand.

other. The work at Newcastle shows that this simple picture is adequate for lightly loaded vehicles operating with small sinkages, particularly in clay soils. It is not correct for heavily loaded vehicles operating with considerable sinkages in sandy soil.[9] Under these conditions traction reduces the supporting capacity of the soil and extra sinkage takes place. In a crawler tractor this causes a tail-down attitude and beneath a wheel it results in redistribution of pressure towards the front of the contact patch. In both these cases performance is reduced.

Current research at Newcastle is aimed at dealing with this phenomenon which has been called slip sinkage. It seems that a third semi-empirical equation relating sinkage to horizontal shear deformation as well as normal pressure is necessary. This will be of the form

$$z = z_p + f(p, j) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad 9$$

where z_p is obtained from equation 7. The soil constants in this equation will be determined quite simply by recording the sinkage of the normal Bevameter annular shear ring during the test currently carried out to determine c, ø, and k. This third equation links the factors in equations 2 and 7 and makes both thrust and rolling resistance a function of slip. We are at present trying to apply this approach to measurements of the performance of driven rigid wheels and tracks heavily loaded to give considerable sinkages in soft sandy soils. Full scale and model equipment is being used indoors in controlled soil conditions in large and small soil tanks. Fig. 5 shows a rigid wheel in the forced-slip tester operating in the large 70 ft × 3 ft 6 in wide × 2 ft 6 in deep soil tank. The wheel is fitted with a device to record the distribution of shear and normal stresses on the wheel surface.

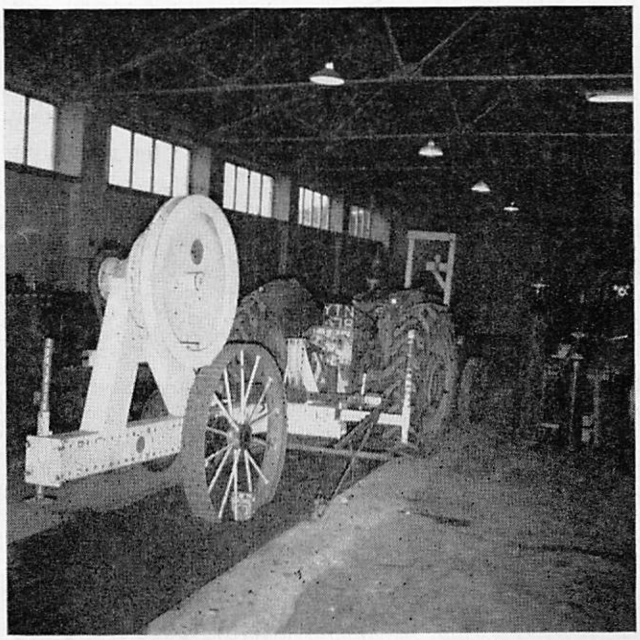


FIG. 5
Apparatus used for measurement of the performance of full sized driven wheels in controlled soil conditions in the laboratory. Torque input, drawbar pull, radial and tangential rim stresses and sinkages are continuously recorded from strain gauge transducers.

The achievement of controlled soil conditions in tanks containing up to 30 tons of soil is a major problem. It has been necessary to divert quite an effort from the research proper to this problem. We hope soon to have in action a rather novel machine capable of emptying and refilling the 70 ft tank and compacting the soil from the bottom upwards in about two minutes.

From this work is emerging a rather distinct approach to the overall problem of soil-vehicle mechanics. The F.V.R.D.E. is able to base its thinking on the soil mechanics of the foundation engineers because of the simple properties of saturated clays. Bekker's equations are largely empirical and are connected to the main body of soil mechanics theory only by the use of c and ø in equation 2. We are now trying to use modified Bekker-type equations, the constants in which can, for the particular case of soils at their maximum density, be calculated from the fundamental soil parameter ø. Equation 7 is a good example of the fruits of this approach, and it is possible to show that $k'_c=7.2$, $k'_\phi=O$ and $n=.17$ for all saturated clays.

It is interesting to apply these ideas to the farm tractor to see how its performance can be improved. For practical reasons agriculture is largely confined to the use of the so-called pneumatic tyre. Unfortunately tyre design is not concerned with traction only. Other major considerations are weight-carrying capacity, resistance to wear at speed on hard surfaces and resistance to damage by shock or tearing. The result of these additional factors is that pneumatic tyres have become virtually solid rubber wheels.

Theory suggests that for traction we need more contact area and particularly more contact length. This will reduce the rolling resistance and increase the thrust by making more use of cohesion and will diminish slip. Obviously this calls for thinner and more flexible tyres; pneumatic tyres, in fact. Such tyres have recently become available and Fig. 6 shows examples of a well-developed commercially available pneumatic tyre (not intended for ordinary farm tractor use). Table 1 shows the result of a test in which one of these tyres was compared with single and dual conventional tractor tyres on two farm soils. The figures show a very appreciable improvement. This type of tyre has proved very successful in U.S. Army field trials. A $\frac{3}{4}$-ton truck fitted with these tyres has outperformed most other military vehicles in snow and jungle terrains.

The farm tractor problem is to combine deflection with strength and resistance to penetration. This is becoming important from a quite different standpoint. Today's more powerful tractors are operating at increasingly high speeds and we have already reached the

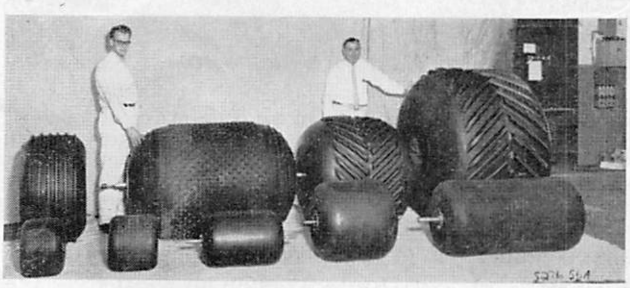


Fig. 6
A group of low pressure pneumatic tyres manufactured by Aviation Products Division, Goodyear International Corporation.

TABLE 1

A comparison of tractive performance between conventional tractor tyres and flexible low pressure tyres, on two farm soils at two inflation pressures. The pressures of the dual tyres were chosen to give the same deflections as the singles. Weight constant in all tests.

Soil	Traction Coefficient $\frac{D}{W}$ at 50% slip at inflation pressure shown in lb. in.$^{-2}$		
	Tyre Size (*Single*) 38×13.6	Tyre Size (*Dual*) 38×13.6	Tyre Size (*Terra Tyre*) 46in O.Dia 24in Width
Loam	.57 at 12 .57 at 18	.70 at 6 .68 at 9	.95 at 4 .80 at 6
Clay loam	.68 at 12 .66 at 18	.64 at 9 .63 at 6	1.04 at 5 .82 at 6

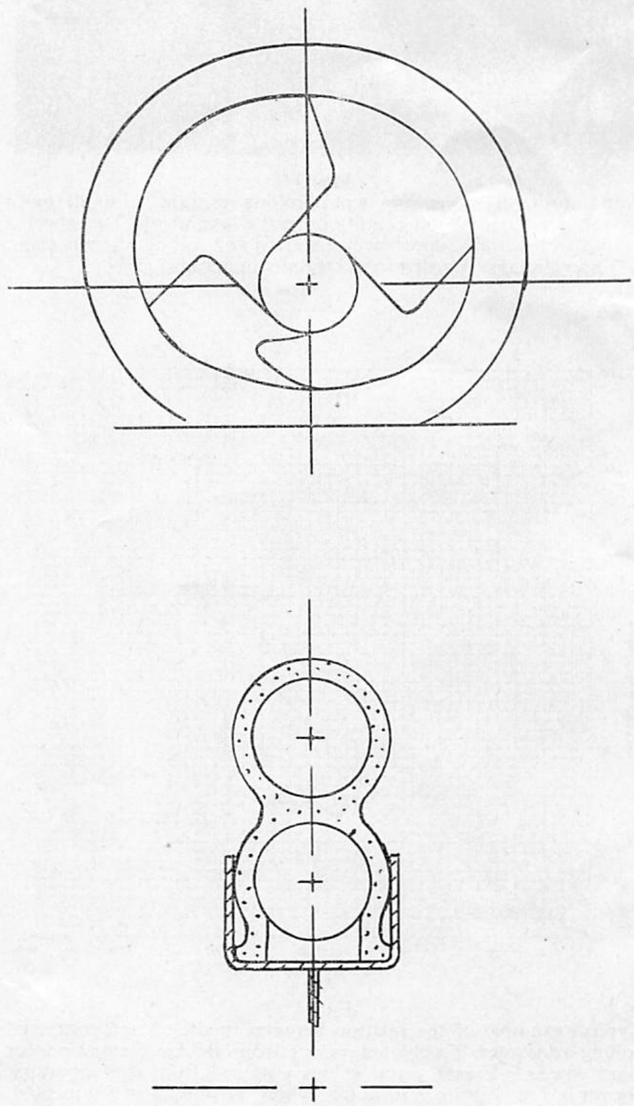


Fig. 7

Two proposals for obtaining a longer contact area from a tyre of a given size.

(*a*) Pneumatic tyre on a resilient rim (Agric. Eng. Dept., Purdue University, U.S.A.).

(*b*) Condual tyre. Outer tyre supported by an inner tyre on a small rigid rim (Bekker—Land Locomotion Laboratory).

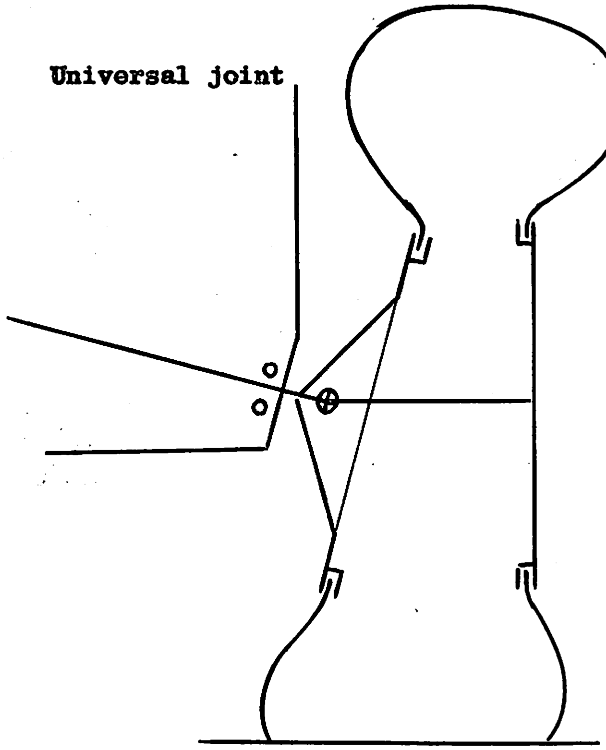


FIG. 8

A proposal for a novel pneumatic tyre and wheel designed to use the rubber of the tyre as the vehicle springing material. It also appears to give a greater contact area (from a recent U.S. Patent Application).

situation in which the limit of working speed is the driver's tolerance of the very rough ride provided by the tractor. There can be little doubt that some form of springing is required and a soft tyre may go a long way towards providing this. Although the problem is difficult, people are thinking about it and interesting suggestions are being made. Two recent ideas to note are the resilient rim[10] and the condual tyre shown diagrammatically in Fig. 7. A recent U.S. patent application describes the ingenious arrangement shown in Fig. 8. The inventor had in mind the development of a tyre with sufficient spring capacity to obviate the necessity for a separate vehicle suspension, but examination of a prototype showed that it also had improved ground contact area as well. The technical evaluation of these three ideas demands knowledge of tyre construction which the writer does not possess but at least the ideas bear testimony to man's inventiveness and we may yet hope that the solid circular wheel is not the final limit of man's ingenuity in this respect.

An example of an attempt to produce a wheel with a longer contact patch for a given maximum diameter was the hubless, spokeless wheel invented by Bekker, and shown diagrammatically in Fig. 9. So far it has not been possible to overcome the problems involved in driving this wheel in typical off-the-road conditions. However, it has been shown that there is no particular difficulty involved in making a solid rubber and steel rim of the required flexibility. The Grumman elliptical wheel (Fig. 9) is an extraordinarily ingenious proposal for overcoming the

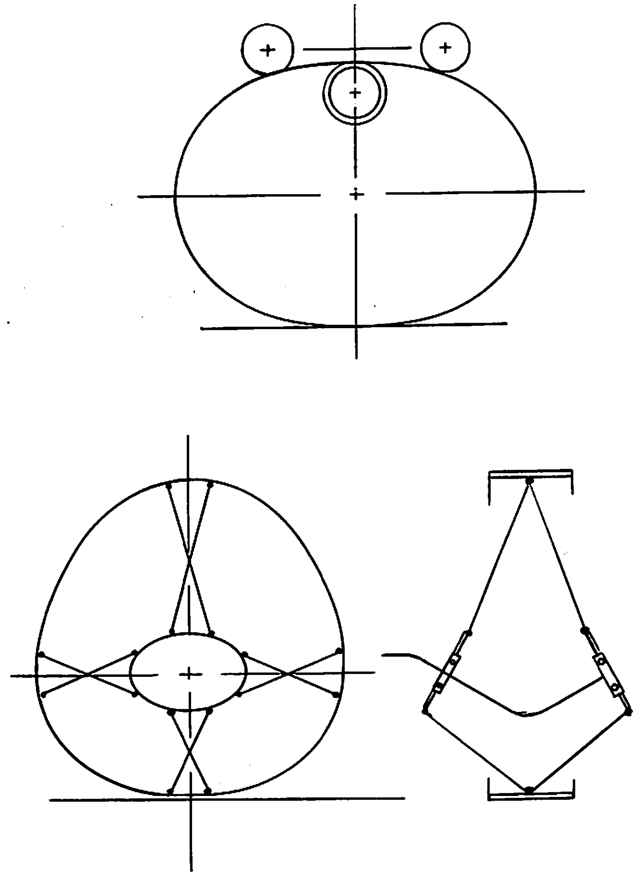


FIG. 9

Two proposals for increasing the effective diameter of vehicle driving wheels.

(*a*) The hubless spokeless wheel (Bekker—Land Locomotion Laboratory).

(*b*) Spoked egg-shaped wheel (Grumman Aircraft Corporation.)

difficulties involved and appears to be a wheel with a simple and effective drive, and good lateral stability.

Since the application of equation 3 to the performance of an agricultural tractor seems to be fairly well justified by Fig. 2 it should be interesting to use it to see where this sort of tyre and wheel development could lead. From Fig. 10 it would not appear impossible to produce

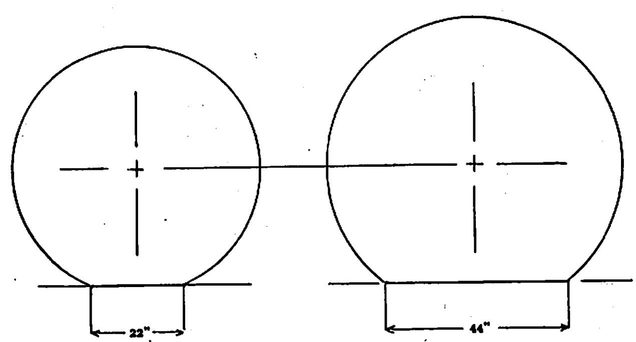


FIG. 10

A comparison of a current 11×36 tyre with a contact length of 22 in with a hypothetical future tyre with the same axle height and twice the contact length.

a wheel and tyre which would have twice the contact length of a present day tyre of 11 in $\times$ 36 in section and yet remain within the same dimensional limits of axle height and overall length. The performance of the two-wheel drive tractor when fitted with this hypothetical wheel and tyre is shown on Fig. 2 for the same soil conditions and assuming a small reduction in rolling resistance from 750 to 600 lb. The result is quite striking, for whilst the maximum pull of the new tyre is a lot less than that calculated for the four-wheel drive, it is nearly the same as the measured pull. At slips up to 15 per cent, which would not be exceeded during normal tillage work, the new tyre would give a result at least equal to that of the four-wheel drive. When it is recalled that full four-wheel drive on this class of tractor costs about £550 extra, it seems that some further efforts to develop better tractor wheels may well be justified.

In the general field of cross-country transport the greatest advance in recent years is unquestionably the development of articulated forms of vehicle. Applied to tracklayers, this principle has produced a large family of transport machines with far greater traction, smoother ride, high speed and better manoeuvrability. Fig. 11 shows a Mark II Polecat as used by the U.S. Army for high-speed personnel transport on the Greenland Icecap. Fig. 12 shows the details of the joint for a similar vehicle to a Polecat. Fig. 13 is the Nodwell RN 200 12-ton carrier. This highly successful twin-engined machine is being produced in considerable numbers and has already earned for itself an excellent reputation carrying cargo over the most difficult Muskeg and snow conditions. The principle of articulation applied to wheeled vehicles has produced, for example, the Gama Goat shown in Fig. 14. This remarkable vehicle is now at the final prototype stage and seems likely to go into production as the U.S. Army Standard $1\frac{1}{4}$-ton truck. The articulated four-wheel-drive loader is becoming a standard form and this will almost certainly be true of logging tractors in the future.

FIG. 11

The amphibious version of the Mark II Polecat. A highly mobile cross-country vehicle manufactured by Wilson, Nuttal and Raymond Engineers Inc. Maryland, U.S.A.

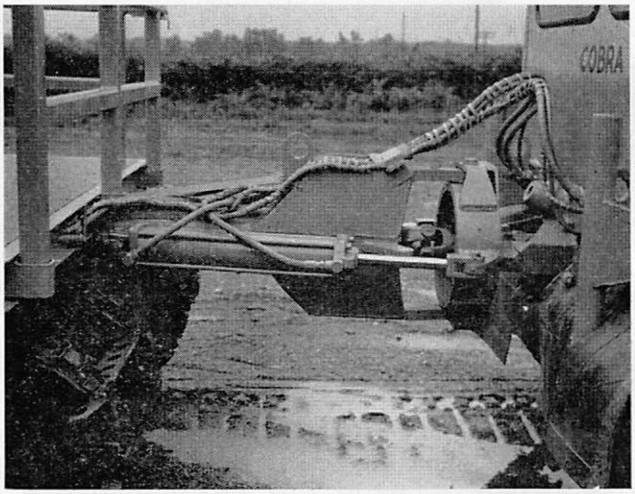


FIG. 12

A typical joint used to connect train-type articulated vehicles similar to that shown in Fig. 11.

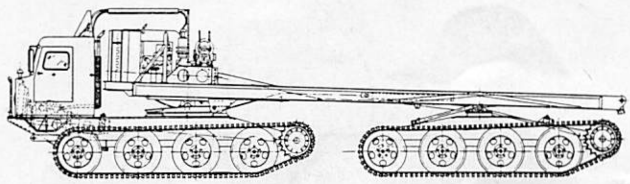


FIG. 13

The RN200, a 12-ton cross-country transporter capable of economical operation in the most difficult terrain. Manufactured by Nodwell Ltd., Calgary, Canada.

FIG. 14

The Gama Goat. A prototype $1\frac{1}{4}$-ton amphibious military truck, manufactured by Ling-Temco-Vought Corporation, U.S.A. An articulated vehicle with torsional and vertical plane freedom but Ackerman steering on front and rear axles.

It is hoped that this paper has made out a convincing case for the study of soil vehicle mechanics, and shown not only that the latter can already illuminate many facets of vehicle performance but also that it is in the process of development into an adequately sophisticated tool for the complex task of developing better cross-country vehicles.

KEY TO SYMBOLS

a	Vehicle ground contact area	in^2
b	Width of ground contact area	in
c	Soil cohesion	$lb\ in^{-2}$
D	Drawbar pull	lb
e	Sum of exponential series	Dimensionless
H	Gross horizontal thrust	lb
i	Slip	Dimensionless
j	Linear soil deformation	in
K	Soil horizontal deformation modulus	in
k_o	Frictional sinkage modulus	$lb\ in^{-2-n}$
k'_o	Frictional sinkage modulus	Dimensionless
kc	Cohesive sinkage modulus	$lb\ in^{-1-n}$
k'c	Cohesive sinkage modulus	Dimensionless
l	Length of ground contact area	in
n	Sinkage exponent	Dimensionless
p	Pressure	$lb\ in^{-2}$
R	Rolling resistance	lb
s	Shearing stress	$lb\ in^{-2}$
W	Vehicle weight applied to driving gear	lb
z	Sinkage	in
ø	Angle shearing resistance	Degrees
γ	Soil density	$lb\ in^{-3}$

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Discussion

MR G. A. ILES (Western Engineering (Delabole) Ltd.) asked whether front or rear sprocket drive was considered best for a tracked vehicle. Mr Reece explained that it was relatively unimportant in the case of an agricultural or industrial tracklayer equipped with rigid tracks. With a military or high-speed tracklayer with sprung or flexible suspension the position was very different, but even so it was not possible to say which form of drive was best without reference to the design of the track suspension in detail.

On peat bogs the aim must be to allow the track to conform to the surface to avoid breaking through the living mat and perhaps here a front sprocket is advantageous.

MR D. R. BOMFORD (Bomford Bros. Ltd.) asked if any further work had been done on the self-locking track, developed during the second World War by Lt.-Col. P. Johnson, which worked in compression. In reply, Mr Reece said that the track Mr Bomford mentioned was applicable to slow-speed industrial or agricultural tractors; high-speed tracklayers must have flexible tracks. A difficulty was that the locking arrangement built into the girder track was subject to wear, so that the track reverted to a non-self-locking form after a few hundred hours of use. In his opinion, an ordinary track supported by an adequate number of track rollers on a rigid girder gave a fairly uniform pressure distribution. Such a design was difficult to improve on by practicable means.

MR P. H. BAILEY (National Institute of Agricultural Engineering) noted, in passing, Mr Reece's reference in his paper to hunting, and assumed this to be in the American sense. In his view, the pursuit of the uneatable by the unspeakable in the unboggable was un-English! More seriously, he referred to the pioneering work of Bernstein, who in 1912 equated sinkage and rolling resistance. He asked Mr Reece to expand on the assumption (by Bekker and by the F.V.R.D.E.) that drawbar pull is equal to gross thrust minus rolling resistance. The interplay of horizontal and vertical forces in the area of contact was of very great interest.

Mr Bailey felt that studies in deep uniform soils were useful for military purposes but of limited value in agriculture. Mr Reece's results were obtained with tractors working on friable cultivated soils—a condition sometimes for test purposes, but not very common in agricultural practice. Most agricultural work was on topsoils which were far from uniform and included stubbles and grasses. Root structures in the soil could well affect soil cohesion, and apparent soil cohesion data could be misleading on this account. Studies at the N.I.A.E. had emphasised the inadequacy of the deep, uniform soil approach.

Finally, Mr Bailey referred to the elaborate types of wheel illustrated in the paper, and mentioned work by Singer in the last war. The Grumman wheel in particular was attractive, but he felt the very complication of these mechanisms detracted from their advantages. He suggested that the logical end-point of terramechanics theory should be to develop high-speed walking mechanisms operated by linear actuators. Mr Reece agreed with Mr Bailey's remarks and said that he had been concerned with deep uniform soils as a matter of expediency, not because they were soils met in practice. At present, the simplest problems encountered in the simplest type of soil had not yet been solved. He hoped soon to be able to deal with more complicated soils, and he emphasised the passage of a vehicle over a soil in fact altered the soil. In general, he was concerned with vehicles having wheels following wheels in the same rut, and the performance of a succession of wheels in such a case was one of the most important problems. He looked forward to the time when enough was known about a single wheel working in a uniform soil to make it possible to move on to the more complex problems.

In his graph (Fig. 2) he had shown theoretical calculations for three types of tractor, from which the 4-wheel-drive layout appeared to have the poorest performance. This calculation was based on a design in which the wheels did not track with each other; the effect of making the wheels track was to reduce the performance still further. He looked forward to investigating the problem further.

MR H. G. PRYOR (Farmer, Essex) asked if Mr Reece had taken into account the effect of speed in relation to slip. Mr Reece said he had not, since the present indications were that the speed of shearing did not greatly affect the strength of soils. The effect of shearing the soil quickly was mainly inertial. If a soil was sheared quickly it was accelerated backwards and a little more thrust forwards could be obtained. While at Detroit Arsenal, Mr Reece had calculated the amount of thrust which could be obtained in this way, in connection with the design of a lunar vehicle. Not much thrust could be obtained in this way even on the moon, where there was considerable inertia but little gravity; the inertial force was still less on Earth.

This summed up the situation: so far as was known, soil was not sensitive to speed of shearing, and neither in agricultural nor in earth-moving operations was speed of shearing taken into account, except where inertia was important. For a vehicle such as a scraper, which accelerated a large amount of soil, inertia was important, but not in terms of vehicle performance otherwise.

Mr Reece accepted that in real life speed made a very large difference. The way to traverse soft ground was to go as fast as possible, simply because the soil was not uniform. It was necessary to use momentum to carry a vehicle across the soft spots in such going, acceleration being obtained intermittently in the less difficult spots.

MR T. SHERWEN (Consultant) then questioned Mr Reece's statement that a 4-wheel-drive vehicle with tracking axles was inferior in performance to one on which the wheels did not track. Mr Reece said that one would expect the first wheel to compact the soil and make it firmer and stronger for the subsequent wheels to operate on. With a self-propelled vehicle which had only to overcome its own rolling resistance this was undoubtedly the case. But, with a tractor having heavily-lugged wheels operating at near maximum drawbar pull and slipping badly, he felt that the slipping front wheels might well be tearing up the bottom of the rut to such an extent as to leave the soil even softer and looser for the following wheels than it had been in the undisturbed condition. With a normal 2-wheel-drive tractor the action of the front wheels in rolling down the soil was beneficial; if one reversed the tractor its performance deteriorated considerably—partly because the trailing wheels then operated in ground churned up by the driving wheels.

MR D. R. BOMFORD asked if this analysis did not ignore the redistribution of weight when the tractor operated in reverse, due to torque reaction. Mr Reece agreed that Mr Bomford's point was valid—load transfer due to gradients and pulling or pushing implements acted in an unfavourable direction when the front wheels were driven. Nevertheless, some experimental work at Newcastle which isolated these factors had shown the rolling-down of the rut by the front wheels to be beneficial.

DR P. C. J. PAYNE (Principal, National College of Agricultural Engineering) said that Mr Reece had shown stress/deformation curves which rose to a maximum and then remained constant. In almost all natural soils this was not entirely true, and in some soils—such as the soils with a substantial root content to which Mr Bailey had referred—it was very far from being the case. In soils such as wet clays with a negligible organic matter content, such a curve might approach the truth. He asked Mr Reece if he adopted this constant maximum as a matter of expediency, which would be understandable, or if such a curve truly described the remoulded soils in which the experimental work has been done.

Mr Reece confirmed that remoulded soils were essential if repeatable experiments were to be carried out and that in his experience remoulded soil behaved in such an exponential manner without a peak. In practice, cementation of soil particles might be encountered. Once cemented bonds failed they would remain broken, so that curves with pronounced peaks would be obtained; organic matter could give a similar effect. The equation applied to the soils used in the laboratory and its simplicity was an advantage.

Mr Reece went on to say that in some cases the peak of the curve might well not be a function of the soil, but of the measuring apparatus. Even if it was a function of the soil, the peak might be so narrow as to represent very little in terms of thrust, and thus might not make much difference to performance. This aspect was another matter he proposed to investigate in the course of time.

MR S. J. WRIGHT (Ford Motor Co. Ltd.) congratulated Mr Reece on the work of his Department at Newcastle, and MR A. J. WALTERS (Massey-Ferguson Ltd.) asked Mr Reece for his opinion on the relative parts to be played by tractor and tyre manufacturers in the production of the ideal tractor tyre. He had been interested to learn, at a meeting, that some farmers were not prepared to accept large, ugly tyres on tractors in spite of the assurance of greater tractive efficiency, on the grounds of appearance.

In conclusion, Mr Reece expressed the view that tractor tyres could be developed to give better traction than at present. He felt there was a lack of co-ordination of design between the tractor and tyre manufacturers and he would be very happy if his paper encouraged the tractor designers to make a closer study of traction problems. The designer could then approach the tyre manufacturer with a more precise specification for tyre performance and it should be possible to obtain improved traction as a result.

CONTROL OF ENVIRONMENT FOR THE GROWTH OF PLANTS IN GLASSHOUSES

by G. P. SHIPWAY, B.SC., M.SC.(AGRIC.ENG.), A.M.I.AGR.E.*

Presented at the Annual Conference, London, on 28th April 1964

INTRODUCTION

In outdoor production of crops the plant environment can be modified to a very limited extent only, e.g. by irrigation and by the application of fertilisers. In unpredictable climates this lack of control adversely affects yields and the quality of produce while continuity of supply is difficult to maintain. When crops are grown in enclosed structures it is possible, in theory, to control all the environmental factors at predetermined levels and thus to produce food by a factory technique. In commercial practice it is not economic to attempt complete control, but as greater knowledge is gained of plant requirements and as reasonably priced equipment is developed, the inclusion of a wider range of factors together with more precise control can be justified. This paper deals with the engineering aspects of the following factors which are commercially important in glasshouses at present:—

1. light
2. temperature
3. humidity
4. soil moisture and nutrients
5. carbon dioxide

There can be considerable interaction of environmental factors, and alteration of one often affects others, e.g. changes in the level of temperature, ventilation or watering will each have an effect on relative humidity.

It should be emphasised that as greater control of environment becomes feasible a higher standard of management is required if a useful return is to be obtained from the capital invested.

1. LIGHT

The energy for photosynthesis is provided by light, the quantity and spectral composition of which determines the type and rate of growth. In addition, the relative lengths of light and dark periods in each 24 hours regulate the time of flowering of some plants. This phenomenon, referred to as photoperiodism, is now extensively used in the production of flower crops out of their normal season e.g. all-year-round Chrysanthemum production. These two entirely different effects of light must be considered separately.

1.1. Light for Photosynthesis.

It is generally accepted that in the United Kingdom during the winter months natural light is the factor limiting carbon assimilation and plant growth. During this period light and growth are directly related, and in broad terms it can be said that 1% more light results in 1% more growth. Apart from sections of nurseries devoted to propagation it is not economical to provide artificial light to supplement daylight. When artificial light is to be used it is important to select the most suitable source. This aspect is dealt with fully by Canham.[1] Thus ways of utilising as much of the natural light as possible must be considered in relation to other economic factors. The effect of shape, design and orientation on light transmission have been measured by Whittle and Lawrence[2] and Edwards.[3]

1.1.1. *Orientation*

Morris quotes[4] evidence that in mid-winter the light transmission in a $\frac{1}{10}$ acre glasshouse orientated with the ridge running east/west is 71% compared with 48% for a similar N/S house. At mid-summer there is little difference, the transmissions being 64% and 66% respectively. Because of the better light transmission during winter propagating houses have been built E/W for many years, but more recently as winter cropping has increased in importance there has been a trend for commercial nurserymen to build growing houses E/W as well.

The mean elevation of the sun in central southern England during the period 26th October to 15th February is about 12°. When the angle of incidence with the glass exceeds 40° the proportion of light reflected from the glass increases rapidly. Thus during this period the south-facing side reflects much less light than the roof inclined at the usual angle of about 27° to the horizontal. To achieve a high overall transmission in a house with traditional roof angles the eaves of the south-facing side should be as high as possible, preferably not less than 7 ft. Alternatively a steeply-sloping south-facing roof can be employed but this must be combined with a shallow north-facing roof if small spans are to be avoided. In view of the added complications in production and erection of the asymmetrical design, particularly in mass-produced glasshouses, the traditional shape with high, slightly sloping sides is the one most used for east/west orientation. This shape is likely to continue to be used although it can be shown that a house of a flattened semi-circular cross section will give better overall transmissions. At present houses of this type are costly and have other limitations.

To achieve a high degree of uniformity of illumination of plants grown in E/W houses it is thought that the beds or rows should run N/S (Fig. 1). With this arrangement the proportion of the space taken up by paths and the relative cost of fixed equipment, e.g. pipework and crop supports decreases as the length of the rows increases. The minimum satisfactory row length is about

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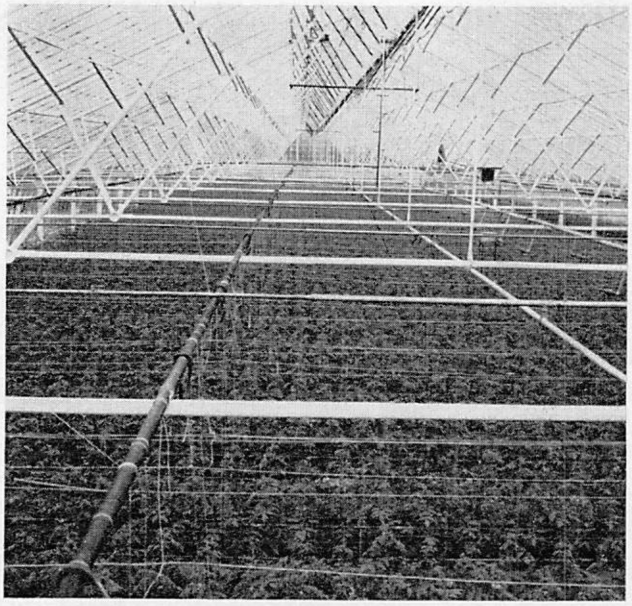

FIG. 1
A 60 ft. wide east/west glasshouse with tomatoes planted in north/south rows. Heating by low level hot water loops running north/south and supplementary high level longitudinal steam pipes

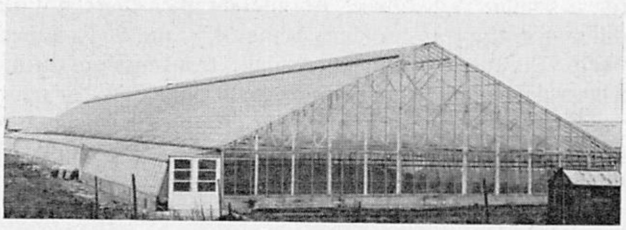

FIG. 2
A 60 ft. wide clear-span east/west glasshouse with a corridor built along the north side

60 ft. and this can be obtained with a single wide-span glasshouse (Fig. 2) or with a multi-span structure composed of narrower spans. Light transmission decreases and becomes less uniform over the structure as the number of spans in a structure increase. On the other hand capital cost per unit area covered decreases as (*i*) the area covered by the structure increases (Fig. 3) and (*ii*) the lateral distance between roof supporting posts decreases until a limit is reached which is determined by the strength of the glazing bars.

Where glasshouses are to be built east/west to obtain a high light transmission it is important to prevent excessive mutual shading. In latitude 51°, i.e. central southern England, at mid-day in mid-winter a shadow is cast approximately 4 times the height of an object. Thus a 14 ft. high ridge of a 30 ft. span house would cast a shadow more than 50 ft. away. To avoid mutual shading of direct sunlight even at mid-day traditional glasshouses would have to be spaced more than their own width apart. However during November to January inclusive direct sunlight supplies only about one third of the total light,[5] the remainder being diffuse light coming from all parts

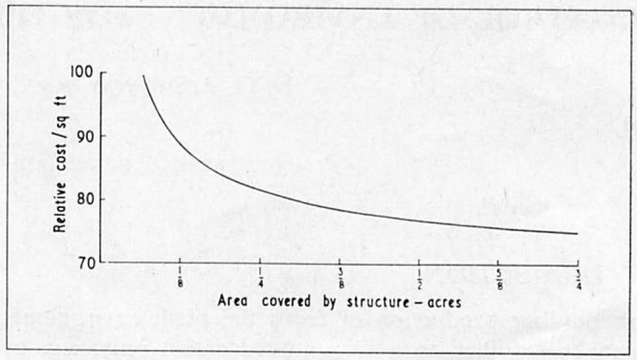

FIG. 3
The effect of glasshouse structure size on cost/sq, ft. covered (Typical 30 ft. spans; base dimensions chosen for minimum cost)

of the hemisphere. Wide spacing must be balanced against reduction in land utilisation, an increase in the cost of services (roads, pipework, etc.), operating charges (heating, transport, etc.), and maintenance costs.

A satisfactory compromise has to be reached in each case. At present it is impossible to give precise guidance but it is generally thought that a desirable target is a spacing of 0.75 to 1.1 times the width of the glasshouses. Height does not increase directly with span, thus within this range the spacing factor can be reduced as the span increases.

1.1.2. *Constructional features*

Besides orientation, size, shape and spacing of glasshouses careful thought has been given to the best way of obtaining a sound structure which obstructs the minimum amount of light and is economical in first and subsequent costs. With good design, the use of galvanised steel or aluminium for the structural members and extruded aluminium alloy for the glazing bars, the amount of opaque material can be kept small even in relatively wide glasshouses. Ways of reducing the amount of opaque material still further are being considered. One approach suggested by Morris[6] is the use of rigid sheets formed to be self-supporting, while another is to use glass wider than the 24 in. width which is normal at present. In Great Britain, Dutch light glass, $28\frac{3}{4}$ in. wide (24 oz.,) has been used for permanent glazing over 5 years and more recently 48 in. wide × 36 in. heavier glass has been tried. It is too early to assess the economic soundness of the latter but first indications are that the structure has a high light transmission.

1.2. *Photoperiodism*

By controlling all the important environmental factors including the relative lengths of light and dark periods, commercial growers are able to produce flowers of a near standard quality to a close schedule throughout the year. Commercially at present Chrysanthemums are the most important photoperiodically sensitive crop. A considerable amount of research has been done on this crop by Dr Daphne Vince[7] and other research workers. The following remarks apply only to chrysanthemums and other short day plants, i.e. those which flower only in short days.

drift. Modulated visible light or modulated infra-red radiation appear to offer the best compromise, and one system based on the use of modulated light has been suggested.[185] System response has been demonstrated on a laboratory scale, but even using moiré fringe techniques to measure the movement of the beacon receiver, it is doubtful whether the tractor could be positioned in the field with an accuracy better than $\pm$ 3 inches.

Faulkner* has demonstrated a standing wave technique using modulated light, which has the necessary inherent accuracy. This particular technique is now being investigated in Russia as a potential method of spacing seeds,[108] and if the difficulties involved in translating the method from a laboratory to a field scale can be overcome a tractor could hold itself within millimetres of its desired course and position. The Sperry Gyroscope Company has developed a spinning light technique for controlling the depth of work of grading and draining machinery. This is a simple and very accurate method, but as yet it is difficult to know how to apply it to tractor control. Probably there is an obvious solution.

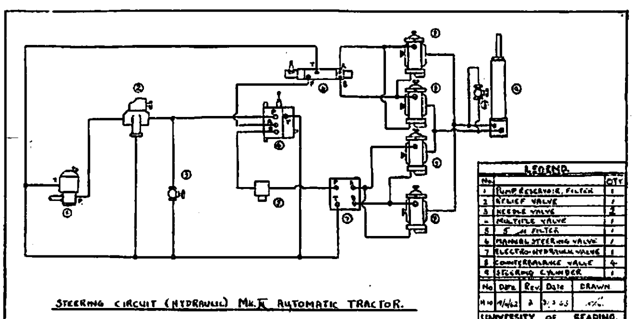

Fig. 4.

Finally Westbrook of Associated Engineering Ltd. has proposed a system[177] calculated to be accurate to within $\pm \frac{1}{2}$ inch, but has not disclosed the method.

The problem of accurate automatic guidance still exists. The leader-cable system[158-176 178-183] is sufficiently accurate, and because it is unaffected by shadows and reflection from buildings and hedges it is very suitable for controlling carting and transport operations and for taking the tractor out to any particular field. It seems ideally suited to work in orchards[184] and soft fruit stands, and has some application to row-crop operations. It is a cheap, robust and reliable system which has been highly developed in a number of non-agricultural operations, from aircraft blind-landing systems[164 167-176 178-183 186 187] to cable and pipe detectors. However, it would be impracticable to lay[179 188] the numerous cable patterns which would be required for the general run of tractor fieldwork.

Summary

The orthodox tractor can be seen to be a highly developed, efficient machine, which is an essential factor in modern power farming, and in terms of value for money British tractors are second to none. Nevertheless the concept of what a tractor ought to be, and what it ought to do, has radically changed during the period of its development. This might mean that a modern machine has been developed in an out-of-date concept. It is suggested that an urgent re-appraisal should be made of the role of the agricultural tractor, in the light of present day knowledge and technique, treating the tractor as the basic machine-tool of agriculture. It must be decided whether this machine-tool should be manually operated, or made semi- or fully-automatic. Various alternative layouts are suggested for consideration if manual operation is retained, and a number of possible methods of arranging semi- or fully-automatic operation are discussed.

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Discussion

MR E. ATKINSON (Shell-Mex & B.P. Ltd.) referred to the problem of defining a 'tractor' and commented on Mr Morgan's statement that diesel engines had superseded petrol/paraffin engines as prime movers in tractors for reasons of taxation rather than because of their technical superiority. He suggested this superiority would in any case have resulted in such a change.

Recently a paper had been read to the Institution of Mechanical Engineers by Dawson, Hayward and Glamann, entitled 'Some experiences with a differentially-supercharged diesel engine'. The development referred to in this paper could lead to very much better torque/power characteristics. This might be a major breakthrough, leading to torque characteristics comparable to those of steam power.

MR MORGAN replied that he was not proposing to give all the answers to these technical questions on this occasion, but rather to ask questions which others might perhaps be able to answer. A point relating to productivity revealed by surveys was that in practice far greater differences were to be noted between tractor drivers A and B than could be accounted for by any kind of differences between tractors A and B. This was a strong argument, he thought, in favour of removing tractor drivers A and B altogether from their tractors and replacing them by little black boxes C, which would not be subject to human failings.

He agreed that diesel engines would have been introduced even without a taxation differential. But, when they were coming into fashion the question that he could remember hearing was always 'How many hours per annum must a tractor operate to justify a diesel engine?' and never 'Is a diesel engine technically superior?', although undoubtedly it was. He thought it was wrong that fuel taxation should exert such an influence, but nevertheless it had done so.

(At this point Mr Morgan showed a research film produced mainly at Reading University, which described the development of simple systems of automatic tractor control and programming.)

MR C. CULPIN (Chief Farm Machinery Advisory Officer, National Agricultural Advisory Service), said that Mr Morgan has invited the audience to re-appraise the requirements of tractor design. Twenty years ago Mr

Culpin had had the opportunity to do this at a stage when a proposed tractor was contemplated. The result was a conventional tractor, which had proved to be successful. He asked himself what the result would be if he did the same now, and so far as he was concerned it would still be an orthodox tractor. It would have twice as much power as 20 years ago; it would have twice as many gear ratios; it would have at least 6 h.p. in the hydraulic system, perhaps with an option of 12 h.p., which could usefully be employed to drive the front-wheels of a tractor, or a trailer or the small hydraulic motors which were becoming more and more desirable. But it would be a conventional tractor.

He suggested that the primary jobs of the British tractor at the present time were cultivations, forage harvesting, transport and so on, for all of which he thought the orthodox tractor was far more suitable than any of the unorthodox alternatives. He challenged Mr Morgan to say which of the unorthodox designs would have won popularity in twenty years time.

Mr A. R. Reece (University of Newcastle) supported Mr Culpin and said that the primary job of the farm tractor was to develop a large amount of traction to pull tillage, tools and trailer. The orthodox tractor made use of the principle of load transfer to use up to 90% of the weight of the tractor and implement to develop traction. This was its virtue and for this reason the conventional tractor would persist.

He thought Mr Morgan had not sufficiently analysed the forces acting on tractors and that he had therefore overlooked the reason why tool-frame tractors were doomed to failure. The tool-frame tractor was based on the use of tools between the axles. One of the tools which had to be carried was the plough, and when ploughing one could not run over the ploughed ground. Therefore the plough must be to the right of the rear wheels of the tractor and if one had more than a single plough body the steering torque would be too great, so that the tractor would swing to the right. The result was that a tool-frame tractor could plough only one furrow at a time, which required 15 h.p. Tool-frame tractors were thus equipped with engines of 15 h.p.

Attempts had been made to plough with more than one furrow by putting the plough at the rear, the tractor becoming a cross between a tool-frame type and a conventional type, and growing large, clumsy and useless. This kind of analysis was required in comparing unorthodox concepts; when it was carried out the Ferguson concept was very difficult to beat.

Mr F. J. Barker (Farmer, Kent) said that he would welcome more power in the small tool-frame tractors in use on his farm. He would also like to see grouping of controls so that the operator could have one hand to steer with, and operate all other manual controls with the other hand. Mr V. H. Hopkins (English Electric Co Ltd) agreed that the correct tractor for use in 1964 was an orthodox one. But in designing a tractor for ten years ahead he thought the University of Reading was on the right lines, as the tractor should obviously be automatically controlled. He had been impressed by the possibility of the use of standing waves for guidance systems. He asked further about the order of increased power Mr Morgan had suggested—would this be 150 to 200 h.p.?

Finally, Mr Morgan replied to Mr Culpin that he did not think any ideal or ultimate form had yet appeared. He had followed Mr Reece's argument on the factors limiting tool-frame tractor power, and agreed that ploughing with one furrow required only 15 h.p. However, the Russians and Hungarians were building tool-carriers of 64 h.p., and managing to plough successfully; he understood the present modal h.p. of tool-frame tractors on the continent to be about 30 h.p. He thought that orthodox tractors were not likely to require much more than 70 h.p., but tool-carriers had been grossly underpowered in the past and he would like to see them equipped with engines of 50-60 h.p.

National Institute of Agricultural Engineering—'Subject Day'

The second *Subject Day* arranged by the National Institute of Agricultural Engineering, Wrest Park, Silsoe, Bedford will be held on 8th October 1964 and will relate to 'Tractor Operator Comfort and Safety'. *Subject Days* are intended primarily for fellows and members of the British Society for Research in Agricultural Engineering, (Wrest Park, Siloe, Bedford).

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Approved by Council at its meeting on 2nd April 1964

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