JOURNAL AND PROCEEDINGS OF THE

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

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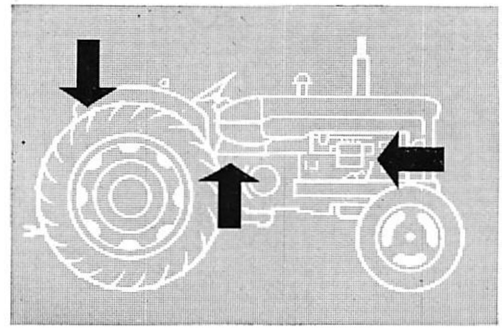

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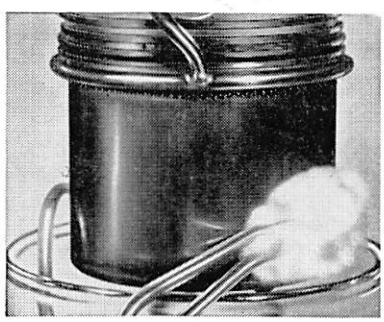
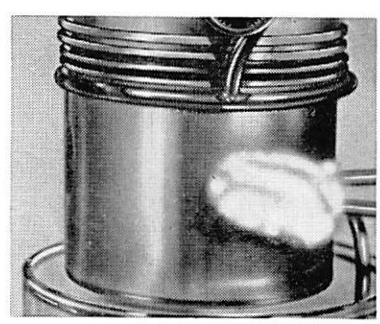
As a transmission lubricant the performance of these oils is at least equal to that of conventional transmission oils in all respects and *superior* in some.

Proof that Tractor Oils Universal keep engines cleaner





In this actual laboratory test two identical pistons were heated to a temperature somewhat higher than they would normally reach in an engine, and a slow stream of oil was arranged to trickle over them. Conventional lubricating oil was used on the left-hand piston and Tractor Oil Universal on the right-hand piston.

The photographs above were taken after three hours.

Notice how the conventional oil (left) has oxidised to produce a brown lacquer deposit, while the Tractor Oil Universal (right) has left the piston still shining bright. This is proof that Tractor Oil Universal has high resistance to oxidation.

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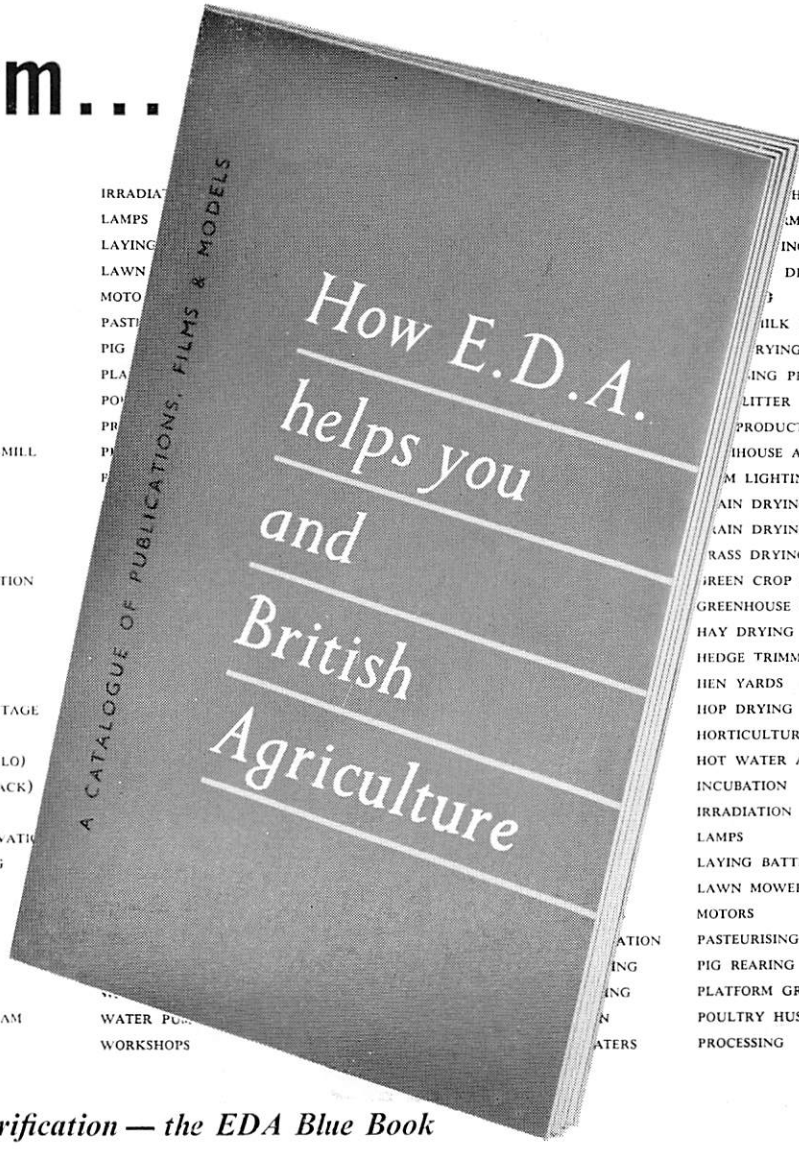

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JOURNAL AND PROCEEDINGS OF THE INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

VOLUME 15 - NUMBER 2 - APRIL, 1959

CONTENTS

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INSTITUTION NOTES

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Annual General Meeting

THE names of the Council for 1959–60 were announced at the Annual General Meeting on May 1st, there being no nominations received other than those put forward by the Council to members. The list will be published in the next issue of the *Journal*, together with the Council's citation conferring of Honorary Membership upon Sir Alexander Glen, who has recently retired from the position of Permanent Secretary to the Scottish Department of Agriculture and who has rendered very considerable services to the Institution.

Annual Luncheon

Nearly 160 members and guests were present at the Annual Luncheon of the Institution, held in London on May 1st, the Guest of Honour being the Minister of Education. A report of the speeches at the Luncheon will appear in the next issue of the *Journal*.

Incorporation

At the Annual General Meeting, also held on May 1st, the President was able to report that the Institution's application for Incorporation had been approved by the Board of Trade, subject to the usual notices published in the National Press. Mr. Chambers added that it was particularly appropriate that this important step should be achieved by the Institution in its twenty-first year of existence.

Overseas Centres

The Council has under consideration applications for the formation of Centres of the Institution in Australia and Southern Rhodesia. Preliminary meetings have been held in both countries, and reports of these indicate that there would be sufficient support from members to justify the inauguration of Centres.

Institution Examinations

Applications to sit for the examinations for the National Diploma in Agricultural Engineering and for Graduate Membership of the Institution are the highest yet received. The Council is particularly gratified at the increase in the latter, as the great majority of applicants qualified for corporate membership of the Institution will in future be accepted by this means.

Lecture for Schoolboys

The Lecture delivered to an audience of schoolboys in London on March 12th by Dr. P. C. J. Payne is reproduced on page 25 of this issue. It was very well attended, the boys mainly coming from Public and Grammar Schools, and the Council is hopeful that it, and similar lectures elsewhere in the country, may be the means of interesting a large number of young men in agricultural engineering as a career.

National College of Agricultural Engineering

The first meeting of the Board of Governors of the College is due to be held shortly. Full information of developments will be made known to members as soon as possible.

Membership Certificates

Availability of Membership Certificates has been delayed pending the grant of Incorporation. Subject to no objections being received as the result of the Press notices referred to above, Certificates will be issued to those members who make application to the Secretary. It is anticipated that the Certificates will be ready for distribution early in June, and copies will be sent to those members who have already applied.

Past Issues of the Journal

A few copies of some of the past issues of the *Journal* are still available if required. Application should be made to the Secretary.

A Lecture presented to an audience of Schoolboys at the Royal Society of Arts on Thursday, 12th March, 1959

AGRICULTURAL ENGINEERING AS A CAREER

by

P. C. J. Payne,* Ph.D., M.Sc.(Agric. Eng.), B.Sc.(Agric.), A.M.I.B.A.E.

INTRODUCTION

This talk is being sponsored by the Institution of British Agricultural Engineers which is a professional body similar in function to, for instance, the British Medical Association. Among the duties it performs is the recruitment of new blood for the industry and, where necessary, it even provides facilities for the training of these new men. Its object in asking me to speak to you this afternoon is to show you, whom we believe to have had some of the finest opportunities in school training available anywhere in the world, that there are splendid openings in its industry. Thus the Institution hopes to keep up the supply of first rate men that are needed if British farm machinery is to hold on to, and even improve, the dominant position it has won for itself in world markets.

IMPORTANCE OF INDUSTRY

Agricultural Engineering is not an industry that often gets into the limelight like the aircraft or motor industries. It has, however, possibly one of the strongest claims to fame in that it is truly wealth creating. For example, it is as true as a short generalised statement can be to say that the threshing machine—A British invention—was the fore-runner of civilization across the American Middle West. Whereas settlers previously had difficulty in providing a harvest big enough to see their families through a long winter, mechanised threshing enabled them to increase output sufficiently to realise the cash income so necessary for further advances. British Agricultural Engineering has always provided for the majority of the needs of our own farmers and since the war has quietly built up its export trade until in 1957, of its £130M worth of production, £80M worth was exported. This was more than the value of the exported aircraft (£70M), ships (£64M) and over half that of the exported motorcars (£152M). In fact, in the list of exported manufactured goods it was second only to motorcars and finished steel and in 1957, accounted for one-third of our national credit in the balance of payments position with other countries. (Reg. Annual Abstract of Statistics 1958 H.M.S.O.)

From this you will be able to conclude that the industry is already in a strong position. Moreover, the future is very promising provided that the brains are forthcoming to keep its research design and productive capacity in the state of advance in which we find them to-day. If the European Free Trade Area is introduced a great but highly competitive new market will be opened up immediately. In any case the home market and that of the underdeveloped countries is expanding all the time.

In this country there is the ever present need to increase food production with a slowly diminishing labour force. This " drift from the land ", as the loss of agricultural workers is often termed, is not a thing to be deplored, but applauded; since it is the principal means by which the standard of living of farmer and worker and, indeed, the nation can be improved. But it offers a constant challenge to all concerned with agricultural production—not least the engineer—to increase output per man and per acre by improved efficiency. Much has already been done of course—real production (allowing for the change in the value of money) has risen by at least 30% (some would say 60%) since 1939 and mechanisation has played a great part in this. We must not, however, rest until rural incomes are as large as urban; and even then there will be the challenge to improve them!

If the opportunities at home are great, those in other parts of the world, especially the tropics, are greater. It is estimated that the population of the world is increasing so fast that in the year 2000 it will be twice what it was in 1955 and even then 50% were near starvation level. Mechanisation can play a great part in increasing output from the vast underdeveloped potentials of Africa and Asia, but here the problems are different. In the Western World we still have to improve designs and produce equipment more cheaply, but the social organisation is available to make efficient use of what is provided. The people of Africa and Asia are in many ways in the same position as we were in U.K. during Feudal times and so besides developing mechanical techniques suitable for tropical conditions those who seek to help must also have an understanding of the social problems. In all probability these will have a stronger influence than those of a purely technical nature.

I hope enough has been said to show you that agricultural engineering is a vital industry and one in which the opportunities for keen men are boundless.

THE AGRICULTURAL ENGINEER

Before trying to describe the variety of professions contributing to the advancement of the industry let me first explain that for our purposes to-day I am not including the man who services equipment. This is not to belittle his contribution; he is as vital as any, but his skill does not fall under the cloak of the professional agricultural engineer and is not our concern to-day.

Agricultural engineering is not a single discipline such as accountancy, for instance, but all who practice it must have one or more of the basic skills of which the most important are probably—

Engineering (Mechanical, Civil and Electrical)
Agriculture, Horticulture and Forestry
Physics and Chemistry
Surveying and Architecture
Economics and Business Management.

The top agricultural engineer must have at least some knowledge of all these subjects though it is probably impractical for the majority of men to obtain a formal training in more than two of them. By far the most

* Lecturer in Farm Mechanisation, Wye College, University of London.

important pair numerically are engineering and agriculture. In the past, facilities for engineers and agriculturists to obtain special training designed to meet their needs for knowledge of each other's subjects have not been available and in consequence they have often had to learn the hard and protracted way,—by personal experience—instead of being shown how to learn from other people's experience, which is really the meat of formal training. During the past ten to fifteen years however, courses have been started to meet the specific needs of engineers and agriculturists to obtain knowledge of each other's technique. So to-day when, as with most subjects, the need for academic qualifications is increasing, it is almost essential to receive a basic training in one branch and then top this up with a shorter course in the other. It is rarely as easy to master your second choice as it is your first and it is therefore desirable to decide at the outset on which side of the industry you wish to be. For the purposes of this lecture, I have divided the industry into two parts which I shall term, "The Manufacturing Approach" and "The Farm Mechanisation Approach". The division is not in fact as clear cut as I shall probably make it sound, but this dichotomy is necessary for clarity.

MANUFACTURING APPROACH

This branch is concerned principally with the design, manufacture and sale of equipment. For each of the three specialisations a basic engineering training is almost essential and for those who specialise in design and/or sales, a knowledge of farming people and ways in this and other lands is equally desirable.

The word "designer" quite rightly has a powerful romantic ring, but do not imagine that the choice rests with yourselves and that all you have to do is to select the right title at the beginning. Design nearly always involves team work based on a drawing office containing numbers of qualified engineers, each responsible for a particular small part of the whole. Much of the work of these draughtsmen is monotonous and has to be repeated several times as a result of prototype failure in the hands of the test team. It is, however, creative and often necessitates an artistic, as well as a mathematical flare. The men most nearly approaching the popular conception of a designer will be the senior engineers in charge of such a drawing office and they will usually have reached their important positions by outstanding ability over a period of years at the drawing board. I seem to remember that, in the film "The Dam Busters" an official said to the hero, "Why should I lend you such and such a bomber?" The hero replied, "Well, I did design it!" It would have rung far truer to real life if he had replied, "Well, I was in charge of the Stress Department when it was designed."

In contrast to designing, selling probably deserves more romantic appeal than it gets. The good technical salesmen, whether he be working for a manufacturer or a distributor is the man who must have the widest knowledge of all. He must be able to appreciate both the customers' and the manufacturers' problems. To do this he spends much of his time out and about and it is often on the reports of the sales departments that firms take their major policy decisions such as whether to design a new product, invade a new market or build a new factory.

I do not propose to say anything about the men who control the manufacturing processes because, important as they are, their training is in no way different for producing agricultural machinery, from that needed throughout the engineering industry.

Of similar importance in principle, though requiring a far smaller annual intake of recruits, is the teaching of, and research into, the manufacturing side of the industry. It might be mentioned, however, that a number of the larger firms attach sufficient importance to this to spend considerable sums every year running their own colleges to train those who will ultimately be responsible for the efficient use of their products. These courses are relatively short and are intended primarily for those already within the industry.

FARM MECHANIZATION APPROACH

This branch of the industry is concerned with the exact tailoring of machines to meet the farmer's needs. There was a time, not so many years ago, when practically all the power used on farms was provided by human or animal muscles and, it meant drudgery for those involved of a kind that not many of us can imagine to-day. Right up to the beginning of the 1939 war the majority of the power used in farming was still muscular, so it can be imagined that almost anything the engineer did to motorise horse and hand operations was heralded as a great advance in mechanisation. Even during, and just after the war, the object was food production at any cost and relatively little attention was paid to economic efficiency. To-day, conditions are very different. Farmers have quite rightly become much more selective and will only purchase equipment if they are convinced that it will reduce their "true costs".

This has led to the development of a new technology probably best termed farm mechanisation. Some of the people employed in it work for firms on the development and testing of new equipment and on market research. Others work for public bodies such as universities, research institutes and the Ministry of Agriculture's Advisory Service. These people are often concerned with the development of completely new techniques involving the use of engineering principles to change the very environment in which crops, animals and stored produce are customarily kept. Yet others are concerned with the dissemination of knowledge both to practising farmers and to new entrants to the industry. This type of work is becoming of increasing importance as the first needs of home farming become satisfied and as the underdeveloped regions of the world become increasingly conscious of the need for mechanisation.

Agriculture or, less frequently, horticulture and economics are the best basic training for this branch of the industry, though just as there is room for a few agriculturists on the manufacturing side, so there is room for some engineers on the mechanisation side.

METHODS OF ENTRY

In the foregoing I have drawn the best picture I can of the industry as I see it. Now I shall try to point out the main routes which are open to young men wishing to become agricultural engineers. It is first necessary to decide whether your aptitude lies in engineering or agriculture. If you are keener on the mathematical sciences such as mathematics itself and physics, then I would recommend the former. If you are better at descriptive subjects such as biology, geography and economic or political history, I would recommend the latter, but this may be misleading because you will often

(continued on page 40)

GROUND ADHESION PROBLEMS OF WHEELED AGRICULTURAL TRACTORS

by A. Senkowski, A.M.I.M.E., M.S.A.E., M.I.B.A.E.

A Paper read at an Open Meeting on Tuesday, 13th January, 1959.

Introduction

SINCE the introduction of pneumatic tyres on agricultural tractors a tremendous amount of research work has been done to elucidate the various factors involved, with the object of obtaining best possible results from such tractors. The theoretical aim, obviously unattainable in practice, is to convert the whole maximum available rear axle horse-power into draw-bar horse-power, without any reduction whatsoever under all field and soil conditions, and over the whole normal speed range of the tractor.

Under most favourable conditions on a concrete road surface we can convert almost 90% of the rear axle power into useful pull. On soft, ploughed ground we must be satisfied with 40%. On firm stubble fields we can reach approximately 75–80%.

Low tractor speeds and high loads are the conditions most difficult to deal with. There are a number of variables affecting both the maximum obtainable pull and the efficiency of converting the fuel burned in the engine into useful work done by the implement.

General design, engine and transmission efficiencies are outside the scope of this Paper, and we will confine ourselves to an attempt to consider briefly the following factors :

Soil properties.
Wheel mechanics.
Pneumatic tyre factors.
Traction augmenting devices.
Tractive efficiency.

Soil Properties

We must first of all examine quickly a few of the principal soil properties, and as these are dictated by Nature and can hardly be changed by human endeavour, they must remain the ruling factor in the adaptation of any agricultural machinery.

(*a*) From the viewpoint of this Paper, the most important and interesting property of soil is its ability to resist shear. Fig. 1 shows diagrammatically a laboratory set-up to evaluate this property. W is the applied weight, T the horizontal force, and P the plane in which the shear failure will occur. It is found that the maximum shear force T equals W times f, where W is the weight ballasting the top lid of the box, and f is the coefficient of internal friction of the soil sample.

(*b*) Loose, dry sand derives its shear strength entirely from the friction developed between the sand grains. It is, therefore, obvious that the shear strength T will be proportional to the compressive load W. Loose sand is a typical " Frictional Soil."

(*c*) Firm, settled clay is the other extreme type of soil. Its shear strength is mainly derived from binding agents (similar to glue). Such soils resemble a solid body like a dry, unfired brick, but part of their shear strength is also the result of the internal friction similar to the one in sand. This type is called " Cohesive Soil."

(*d*) Fig. 2 shows some typical results obtained in the shear box (Fig. 1). These indicate that no soil resistance can be developed without a proportional displacement, and also that after trespassing, a certain critical displacement (*i.e.*, slip), the maximum shear force T which the soil can sustain decreases rapidly for cohesive soils like clay and fairly slowly for frictional soils like sand. A good idea of the importance of slip is obtained by examining Fig. 3, referring to a track-laying vehicle. Every time the track moves through a distance S the loss of forward travel of the vehicle amounts to the length of soil compression shown at grouser 5. Wheels behave in a very similar way, but rather worse, since the length of ground contact S is so much shorter.

All these considerations apply to homogeneous soils (like, for instance, desert sands) and must be very cautiously applied to actual farming lands with their varying moisture content and gradient, vegetation root systems, degree of compactness, etc.

Non-Driven Wheel

We can examine now in some detail the mechanism of weight transfer between a non-driven wheel and the ground. Fig. 4 is a section through the centre plane of a wheel and the associated part of the ground. W represents the weight applied, R the force necessary to overcome the rolling resistance, and S the soil reaction.

Fig. 5 is a section perpendicular to the first showing the deformed tyre and the pressure distribution in the ground. The heavily shaded area is the pressure bulb supporting the load, and the two lighter shaded areas are the soil masses under failure.

The study of these two sketches will permit us to make cautiously the following observations :

1. Shear strength of the soil resisting the displacement of adjacent layers enables the ground to carry the vertical tyre load.

2. Rolling resistance is proportional to tyre sinkage. An increase of tyre diameter extends the length of ground contact area shown in Fig. 4 and reduces, therefore, sinkage. Furthermore, the angle of plane P is reduced, thus pushing the resultant soil reaction S more towards the vertical, which, in turn, reduces the rolling resistance component R. Increase of tyre width and flattening of the ground contact area in Fig. 5 also reduces sinkage. The area of the triangular pressure bulb proportional to W^2 makes it clear why a tyre of, say, double width has four times the load-carrying capacity for the same sinkage. Rolling resistance, however, does not respond too well to increases in tyre width. Fig. 6 and 6b give a qualitative idea of the respective influence of width and diameter of the wheel on the rolling resistance. Low inflation pressure produces identical results.

3. Reduced inflation pressures are harmful on hard, firm ground surfaces. They increase the tyre deformation work and thus also the rolling resistance, sinkage under these conditions being no problem.

Driven Wheel

Let us now consider a loaded and driven wheel fitted with a smooth tyre. The load W distributed over the contact area of the tyre enables the soil to transmit a tangential reaction to the wheel equal to $W\mu$, where μ is the conventional coefficient of friction between the mating surfaces. On hard ground there are no further observations to be made.

In all average field conditions, however, the soil is subjected to pressure as shown on Fig. 4. This pressure enables it to take shear loads resisting the tractive force up to a limit Wf, where f is the coefficient of internal friction (see Fig. 1). When this limit is exceeded the soil will collapse approximately along the shear lines shown on Fig. 8. We can appreciate that to use the internal soil friction to its full advantage the coefficient of friction between the tyre and the adjacent soil surface must be at least equal to the coefficient of internal friction of the soil. With a pneumatic tyre, even smooth, without a tread pattern, working on a relatively dry and vegetation-free surface, there is little difficulty in this respect. Smooth steel tyres are very disadvantageous, as steel against soil has generally a coefficient of friction lower than the internal coefficient of soil.

Fig. 9 shows diagrammatically a wheel fitted with grousers. On sandy homogeneous soils the area between grousers 1 and 2 will shear on an arc connecting the tips of the grousers, thus providing very little advantage over a smooth wheel. Grouser 2 will make a small contribution, as an additional volume of soil will be subjected to shear, so long as the space between two adjacent grousers is not filled up with compacted soil as shown between grousers 3, 4 and 5.

Fig. 10 shows the action of a single, rather high grouser in a homogeneous frictional soil. Theory and practice agree that only small tractive forces can be thus produced.

It is regrettable that the above considerations hold good where the grousers are steel on steel wheels, steel on pneumatic tyres, or rubber bars on rubber tyres.

This somewhat disappointing statement, however, is only correct for homogeneous sandy soils. On more cohesive soils, of which clay is an extreme example, and also in other conditions, bars and grousers come into their own in the following way :

(*a*) On concrete surfaces covered with a film of water or a slippery film of any nature the rubber bars penetrate the film and obtain a good grip by direct contact with the firm surface.

(*b*) The same action occurs on hard (cohesive) soils covered with a slippery layer, as long as the latter is not too thick.

(*c*) There are many field conditions where a firm, hard ground is covered by a loose layer of soil, sand or gravel. Rubber bars sweep this layer away and reach firm ground contact. The bars are, therefore, arranged under such angles as to push the loose soil sideways out of the tyre contact area. A somewhat similar action can be observed on turf or stubble. Unfortunately, a fair amount of wheel slip is required, so that traction efficiency is impaired.

(*d*) On cohesive soils, yet soft enough for the bars to penetrate, a sort of pinion and rack effect can be produced. The soil teeth are capable of taking shear forces larger than those which could be dealt with by pure frictional contact with a smooth tyre. Reversing the chevron tread on the tyres to point forward to the direction of travel may give a slight gain on some rare occasions, as long as the soil is not too cohesive.

(*e*) Strakes can penetrate deeper into the ground than rubber or steel bars. If they reach deep enough to meet a firm soil layer, traction can be greatly improved. Such devices, however, do a fair amount of digging, consuming power and fuel.

Summing up, we can say that traction is derived from the frictional contact between tyre and soil and from a sort of pinion and rack action between wheel grousers and soil.

Pneumatic Tyres

After this short introduction, we can examine the principal factors in pneumatic tyre design available to the engineers, and also at the same time try to make a number of practical comments.

1. *Diameter*

Large diameters are always favourable in respect of traction, rolling resistance and slip. A wheel of a very large diameter would actually be as good as a track. On harder grounds the improvement is much less noticeable. There are, however, practical tractor design and cost limitations which bring us rapidly to a point of poor economic returns.

2. *Width of Section*

Increase of width is the easiest way to combat sinkage. To obtain the full benefit, it is, however, necessary to lower the inflation pressure, otherwise the gain—at least, with conventional tyre sections—might be somewhat disappointing. Tyre sidewall wrinkling is the danger associated with low pressures, so that the manufacturers' advice should be followed very strictly.

It must be remembered that a given rim size will only permit a certain maximum section of tyre to be fitted. Beyond a critical limit, instability in the transverse direction and damage to sidewalls will occur.

Wide sections have by far not the same beneficial effect in regard to slip as large diameters. This can be understood by considering the advantage of a long ground contact line shown in Fig. 3.

However a wider section reduces the unit pull load per 1 in. of length of bar and will contribute towards better bar life under heavy pull adverse conditions.

3. *Rim Size*

The modern tendency is rather towards wider rims, even for the same tyre sections as used heretofore. This is quite justified, as a wider rim increases slightly the section of the tyre. Furthermore, transverse stability is improved, and also if necessary a wider rim can take again a wider tyre section.

It must be mentioned that in our country tyre sections above 11 ins. are very unpopular, as there is no room in the furrow for anything wider. Ploughs wider than 12 in. furrow width are hardly used, due to the conditions and/or traditions prevailing.

4. *Shape of Section*

Present-day conventional tyres have an arcuate outer part of the section (disregarding the bars) approaching a semi-circle. There are good, practical reasons for it, of which ease of self-cleaning is a major one. It can be assumed that a tyre with a more flat outer section will give better results on dry sand without the necessity of very low inflation pressures. I believe that such tyres are being produced already experimentally.

5. *Bars (Cleats)*

The variable design factors are :

- Height.
- Width.
- Number (or pitch).
- Angle.
- Pattern.

From the viewpoint of traction alone, it would be best to use rather high and narrow bars to obtain deep penetration. The mechanical strength of rubber and the stiffness of the carcass are limiting factors leading all manufacturers to similar conclusions, resulting in an almost standardised bar section. Tyres with extra high bars are produced as special, and they give good results on wet, soft soils, but not on sand. On hard ground they give no advantage and wear out rapidly.

The pitch and angle are compromises dictated by the necessity to provide self-cleaning action and also reasonably smooth rolling on harder grounds. Tyres used in this country are primarily designed for wet Spring and Autumn conditions, and it would seem that for dry countries finer pitches and smaller angles could be better.

In our country a pattern of the open-centre type has been standardised for field work to obtain good penetration and self-cleaning at a sacrifice of roadworthiness. An additional advantage of this design is a reduced transversal and circumferential stiffness favouring the accommodation of the tyre to the ground. In other conditions than ours, the open-centre type may not necessarily be the best.

6. *Tyre Carcass*

The ideal carcass would be very flexible, yet would provide a firm base for the bars, would be immune to flexing fatigue, immune to external damage and would not wrinkle even under highest driving torques, yet being able to withstand high internal pressures and high wheel loads.

These requirements are contradictory and are met generally by a compromise of 4 or 6 plies, the choice depending on the tyre size and service loads.

Low inflation pressure and high number of plies is an unfavourable combination.

7. *Inflation Pressures*

Lowering the inflation pressure increases the area of ground contact, as long as the ground surface can sustain a unit pressure (expressed in p.s.i.) approximating the internal tyre pressure. We can also say : If the soil is softer than the tyre, reduced inflation pressure is of no advantage.

Wrinkling of the sidewalls is a deadly enemy of low inflation pressure, which, on the other hand, favours good tractive efficiency. It is, therefore, hoped that future technical developments will enable us to use lower inflation pressures without the associated wrinkling problem.

8. *Tyre Loading*

The trend in tractor design leads all the time towards higher power to weight ratios. This is technically and commercially correct, and forces us into the necessity of increasing adhesion (chiefly at lower speeds) to be able to utilise the full available engine power for traction.

Tractor designers have been quite successful in the past to concentrate a larger proportion of all the vertical forces on the driving axle. These are derived from the tractor and mounted implement weights and also from downward vertical soil forces on the implement. There is naturally a practical limit to this procedure, and beyond this limit ballasting the rear axle becomes a necessity.

Any added ballast increases the tractive force available from the tyre, but also increases rolling resistance in all conditions and consumes additional power in uphill work. On all but very firm and level surfaces ballasting above the critical amount will reduce the power available for the implement. Furthermore, running the tractor at, say, 50% of its maximum pull with ballast catering for 100% pull can be a great waste of fuel.

It is, therefore, generally agreed that the ballasting weights should be easily removable.

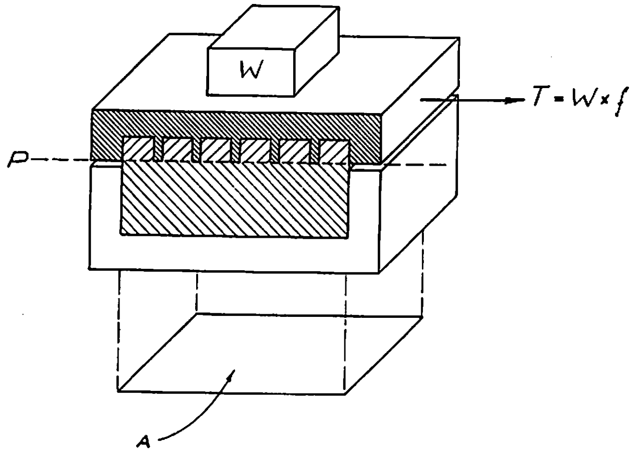

FIG. 1

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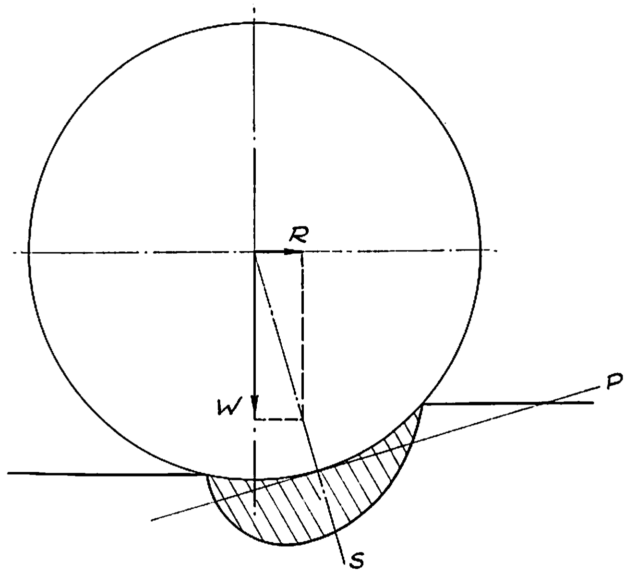

FIG. 4

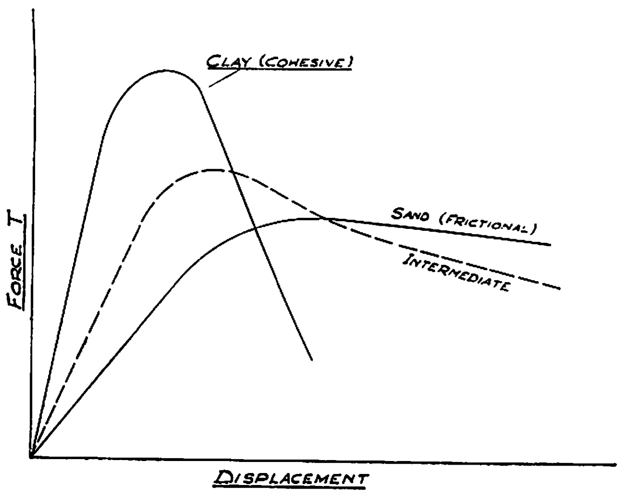

FIG. 2

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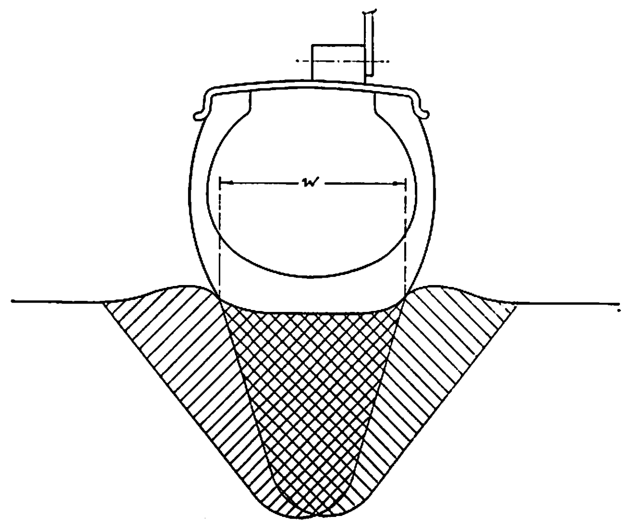

FIG. 5

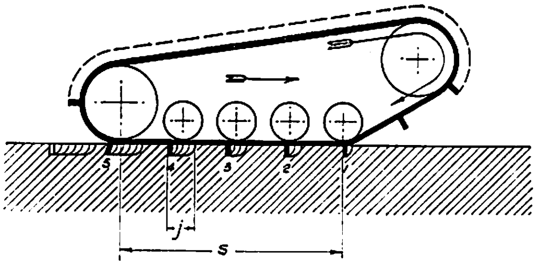

FIG. 3

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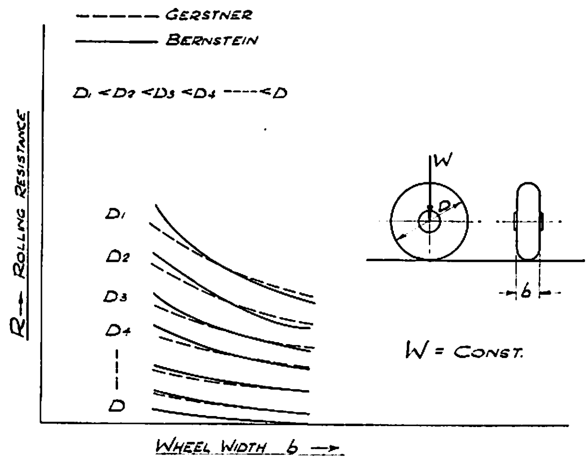

FIG 6

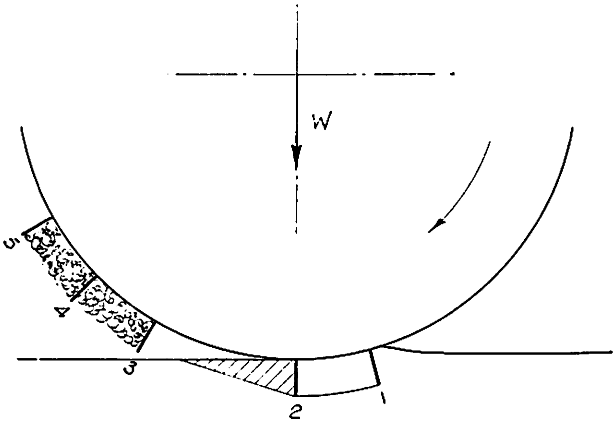

FIG. 9

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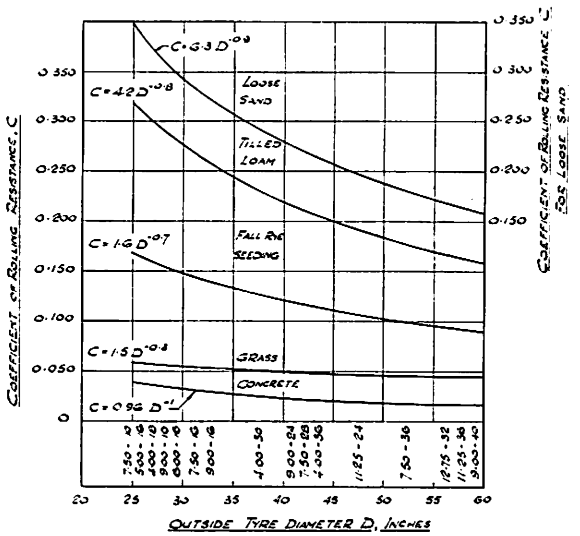


FIG. 6B

BARGER

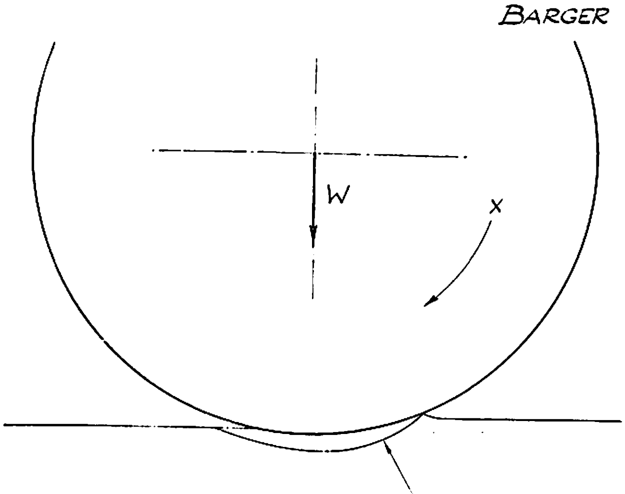


FIG. 8

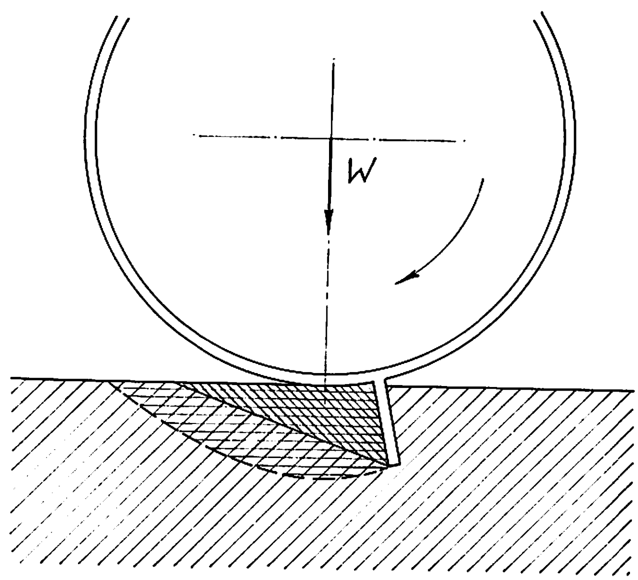
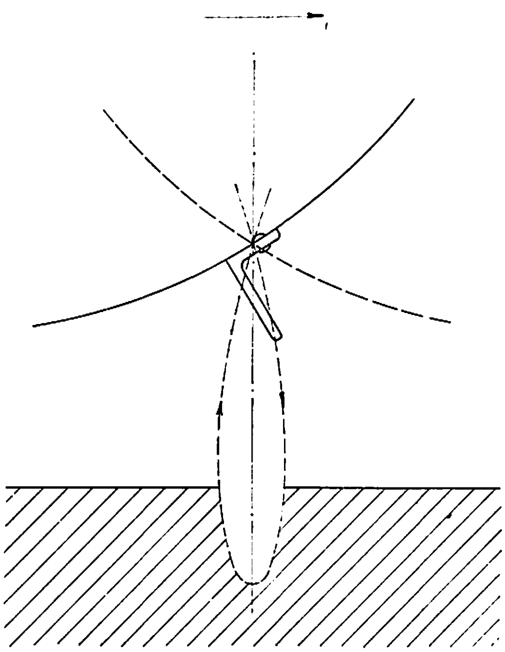


FIG. 10



(KÜHNE)

FIG. 13 BEKKER

9. *Water Ballast*

In spite of the tedious manipulation, this form of ballasting is very popular, chiefly due to the low cost.

There is, in addition, one great technical advantage—namely, a reduction of sidewall wrinkling at or near the 100% water fill mark. Water ballasted tyres can, therefore, be run without undue damage to the sidewalls at much lower inflation pressures (where this is desirable).

Traction Augmenting Devices

We have already mentioned the main limitations of the pneumatic tyre, which can be summarised as follows :

Wet clay, certain kinds of vegetation, stubble, snow—all provide a lubrication layer between the ground and the tyre. If the rubber tyre bars cannot penetrate sufficiently to get hold of firm ground underneath, ballasting is of little use and even harmful under extreme conditions. Traction augmenting devices become, therefore, the only means of improvement.

Girdles

The cheapest and mildest device are the well-known tyre girdles. They cut through the slippery surface and obtain good grip from the firm soil underneath. Lugs can be fitted to the cross-bars, giving better penetration. The increase of rolling resistance is moderate, but proportional to the gain in traction. If not fitted with additional lugs, it is possible to negotiate hard patches or even to drive on the road at moderate speeds.

On sandy soils the gain in performance is marginal, but on heavy and moist clays improvements in traction up to 50% can be expected.

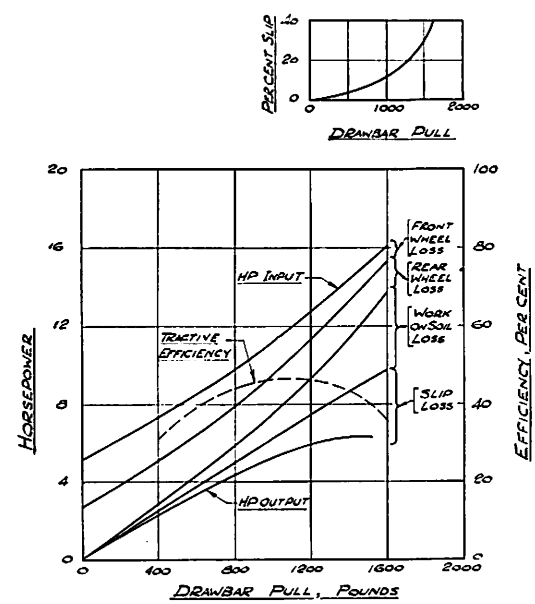
The penetration of the girdles is moderate, and if adequate traction grip cannot be obtained in, say, the first 2 ins. of the ground, recourse must be taken to the next step.

Strakes

There are retractable and non-retractable varieties available. The first type is generally preferred, as they can be stowed away for normal conditions and road work. Furthermore, most of them can be extended to variable depth, and this is quite an advantage.

It must be pointed out that the strakes disturb the soil, each of them digging into ground in the fashion of a truncated figure 8 (see Fig. 13). This consumes power and, therefore, they should not be made to protrude more than necessary for a given set of conditions.

On wet clay traction improvements up to 200% have been reported.



TRACTOR OPERATION ON CLAY LOAM
PLOUGHED 10 IN. DEEP

FIG. 18 O'HARROW

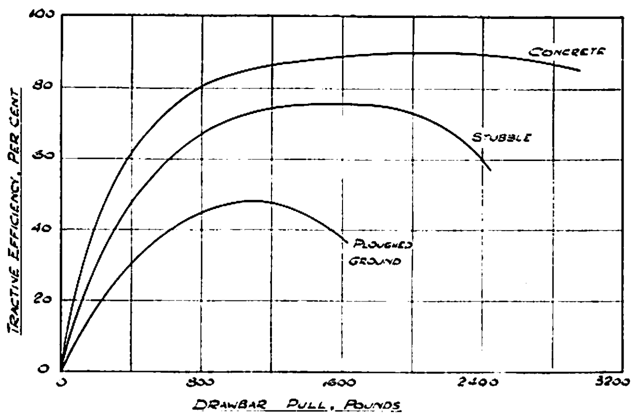


FIG. 19

O'HARROW

Cage Wheels

When tyre sinkage becomes the predominant factor, cage wheels enjoy an increasing popularity. They are fixed on the outside of the wheel, their diameter being smaller than the outside diameter of the tyre. The number of cage blades, their width, length and section vary according to the conditions of use and the experience and ideas of their designers. Excellent service is obtained in paddy fields and on moors, as these wheels reduce greatly the unit ground pressure and improve traction due to the large slices of soil submitted to shear. In a way, they are a further extension of the strake principle.

A further advantage is that the tractor can move on hard ground with ease, as the cages are out of contact.

Rolling resistance is high and they should, therefore, not be used where other aids suffice.

Tyre Tracks

This is a rather expensive attachment which can still be reasonably easily fitted to standard tractors. It is touching the borderline of the full track laying vehicles.

Their action is two-fold. First of all, a continuous mat consisting of two rubber bands and closely spaced cross-bars is being laid for the rear track wheels. Secondly, the steel cross-bars, which can have various sections, are putting a large surface area of the soil into shear, thus augmenting the available traction.

The best application for tyre tracks is snow, for which they were originally developed. The gradual compaction starting at the lightly-loaded jockey wheel is a correct action for snow. Wear of cross-bars and rubber bands is fairly good in those conditions.

When there is complete absence of stones and abrasive matter, the rubber bands can be replaced by chains. Life is surprisingly good, as snow has a certain lubrication action on the chain links. This Norwegian design is proving very popular in Scandinavia.

Good results are also obtained from the rubber band type of tyre tracks in soft sand, rough terrain, woods and shrubs, as climbing over obstacles is greatly facilitated by the combination of mat laying, small load on the jockey wheel, reduced unit ground pressure and relatively sharp steel bars.

An interesting application is on soft prepared seed beds, where tyre tracks leave hardly any trace on the ground after the passage of the tractor.

There are, however, several disadvantages and limitations.

In most conditions, except snow, wear of cross-bars and rubber bands cannot be avoided. Sharp stones are a deadly enemy to this device. In hard usage the conventional tyres suffer some damage from the driving pommels on the inside of the cross-bars. This could be overcome by a special tread on the tyres, but such tyres would not do for general use.

Steerability of the tractor is adversely affected and puts a limit on the amount of load which can be transferred to the jockey wheel as this load is taken off the front axle, impairing steering.

The tracks are too wide to be accommodated in the furrow whilst ploughing, and, furthermore, the tyre tracks are not capable of carrying large transverse forces, as the rear wheels tend to ride out of the tracks, unless special side lugs are provided.

Lastly, these tracks are not suitable for speeds above 5–6 miles per hour, as wear becomes prohibitive.

Full Tracks

This adaptation is probably the limit of what can be done on the conventional agricultural tractor without going to a full-scale conversion into a proper track layer.

The load on the jockey wheel is considerably increased by a suitable design and the unit ground pressure figure is quite favourable. Steering is effected by the use of the independent turning brakes, but would be quite inadequate for normal agricultural use.

Several units as shown have been used with great success by Sir Vivian Fuchs' Antarctic Expedition, proving once more the amazing flexibility of modern agricultural tractors.

Tractive Efficiency

The power developed at the rear axle of a tractor cannot be transferred to the draw bar without losses.

First of all, a part of it is used up to overcome the rolling resistance of all wheels in ground contact. The main factors influencing this resistance have been discussed in this Paper.

The second source of power loss is gradient resistance, favouring light tractors as long as they provide adequate adhesion. .

The third cause is wheel slip. The percentage of wasted work is again directly proportional to the percentage of slip. Unfortunately, no tractive force can be developed by a wheel without some slip. In most field conditions the best efficiencies are obtained at 10–15% slip.

On anything but very hard and firm surfaces another factor becomes pre-eminent and this is the work wasted in cutting, churning and displacing the soil. This loss is roughly proportional to the slip loss, and in soft ground conditions may become even higher than the latter.

It is disappointing, but not surprising, that tractive efficiencies over 40% must be considered as reasonably satisfactory in actual field conditions. Fig. 18 is a good example of efficiency variations on one particular tractor.

Fig. 19 presents typical efficiency curves for a few characteristic ground conditions.

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Opening the discussion, MR. W. M. CATCHPOLE said that the greatest single factor affecting the development of traction by wheeled tractors in agricultural operations was the wide range of work which the wheels were expected to perform. The operations extended from the heaviest ploughing in difficult soils to the lightest work in seed bed preparation. Added to that, the endless variation in soil conditions, due both to soil structure and weather conditions, further complicated the problem.

One could not but agree with Mr. Senkowski's conclusions, and the speaker would therefore attempt to stimulate discussion about the probable future trends of tractor wheel development. He commended Mr. Senkowski's last paragraph on soil properties where he advised caution in the application to actual farming lands of the findings he had put forward.

It had been shown in Fig. 1 that the maximum force $T = W \times f$. It was the factor " W," representing the applied weight, which he wanted briefly to discuss. Most of the research work on tractor driving wheels had been planned on the assumption that the above equation was fundamental.

That weight had been applied to the wheels in a number of ways. Mr. Senkowski had detailed some of them under the heading " Pneumatic Tyres." In the beginning of that passage, reference was made to the trend towards higher power to weight ratios. That was a logical movement, but only accentuated the problem of wheel adhesion.

Since the author had so fully dealt with the pneumatic tyre and its main limitations, the speaker would direct his remarks towards the other types of wheel. Before doing so, however, he had to ask why the author had not mentioned twin pneumatic-tyred wheels.

All types of soil had a resistance to shear derived from various properties. That resistance could be exploited by wheels without necessarily placing the soil in engagement with the wheel under compressive load. Provided that suitable projecting lugs could be so mounted on a wheel rim that they cut into the soil surface until the more firmly settled layers were reached, the shear resistance of the soil could be encountered without compressive load being applied. Many types of tractor wheel had been designed to utilise that principle. The majority had been based on a disc or very narrow rim forming the wheel with projecting lugs on one or both sides, or on the periphery, and had been aptly named " skeleton wheels." The form of the lugs usually permitted them to enter and leave the soil with the least possible displacement, and the narrowness of the periphery of the rim was considered to reduce the rolling resistance.

Turning to the general requirements of tractor wheel users, the speaker said that a number of factors affected the tractive efficiency of wheels. They could be placed in the following order of importance :—

1. Ground adhesion or grip.
2. Low rolling resistance.
3. Minimum soil displacement.
4. Ability to effect 1, 2 and 3 under the widest possible variety of soil types and conditions.

On the first point—as the author had indicated, the most important property of soil was its ability to resist shear. Tractor driving wheels had to be designed to exploit as fully as possible that resistance. The equation $T = W \times f$ could hold good only where " W," the applied weight, was a permissible factor. To what extent was it possible to exploit " T " in the absence of " W " ? The author had drawn the conclusion that no soil resistance could be developed without a proportional displacement. How was the proportion calculated ?

On the second and third points, rolling resistance was closely linked with soil displacement or " tyre sinkage." On the majority of agricultural cultivation operations soil displacement by the tractor wheels was not acceptable. Applied weight " W " which caused tyre sinkage could produce the result where the point of critical displacement was reached in some soil conditions before any tractive effort was produced. Soil displacement was expensive in terms of power, and wheels which displaced a large amount of soil in order to develop traction could produce only low tractive efficiency—and that even should the degree of displacement be acceptable. Wheel tyre profiles which displaced the soil by means of a digging action were expensive in terms of power consumption, and the digging action could often result in the wheels rapidly sinking into the soil to such a degree that the tractor stalled.

On point four—users of wheeled agricultural tractors were interested in this fourth point and usually became critical of wheels when they failed to produce tractive effort, irrespective of soil conditions. Wheels normally failed under extremes of either tractive loading or soil conditions. It had to be remembered that many quite small agricultural enterprises had to deal with a very wide range of soil types. It was not uncommon to find sand at one end of a field and clay at the other, or even clay in the middle and sand at either end.

The author had referred to the " rack and pinion " effect. That was the most promising line of investigation. Dry sand would not, at first sight, appear to be a promising soil for developing the rack and pinion effect. Wet clay, on the other hand, offered good conditions for penetration cleats or lugs to enable firm soil layers to be reached. Many clay-type soils were extremely adhesive when damp and would stick with almost equal facility to steel or rubber. Those soils readily filled up the spaces between the lugs or projections on the treads of both steel and rubber tyres and offered the greatest challenge to the designer of tractor wheels. The problem was to produce a design of wheel having lugs which would penetrate deeply enough to reach the firm soil layers yet offering no surfaces upon which the soil could stick and accumulate.

The users also required a wheel which would traverse hard surfaces, such as roads, at useful speeds, but without damage to the surface or the tractor. Where it was necessary to use traction augmenting devices they should be readily withdrawn or removed for road travel.

High tractive effort was not required in the cultivation of sandy soils, and in that case rubber tyres were very good.

The author had shown how complicated was the problem of selecting equipment to produce traction. Although the pneumatic tyre was supposedly a simple device, they should try to reduce the number of augmenting devices which were necessary with its use.

In reply, THE AUTHOR said that there was nothing in what Mr. Catchpole had said with which he basically disagreed. The author had not mentioned the use of twin rear tyres for the simple reason that he could not possibly cover every variation of equipment. Nowadays it was generally agreed that the twinning of rear wheels was a less efficient way of combating tyre sinkage than using a wider single tyre. It was convenient, of course, but it was also expensive, and no doubt that was another reason why it had not become popular and why manufacturers were not making greater efforts to sell the idea. Another objection was that twin tyres would not fit into a furrow.

He had covered the rack and pinion method in the Paper. He emphasised that benefits from it could be derived only in those soils which had at least a partial component in their shear resistance derived from cohesion. Homogeneous dry sand was the other extreme.

Mr. P. H. Bailey, N.I.A.E., said that in the notation of Fig. 1, the statement $T = Wf$ was of course the special case (*b*) of dry sand. Mr. Catchpole had implied that wheel research workers had taken this expression as the basic equation governing wheel performance, but in fact the Coulomb-Mohr equation $t = c + \sigma \tan \phi$ (which might be integrated to $T = cA + W \tan \phi$ for total weight and pull) was used as the general expression. This included a term for cohesion. Fig. 3 which followed Bekker's treatment gave a good idea of the mechanism of generation of slips less than total sliding, but the speaker was not altogether happy that the expression given by Bekker[1] (based on consideration of a track) was satisfactory for a wheel.

The relationship between rolling resistance and tyre sinkage was only one of direct proportion when edge effect was negligible and soil reaction pressure independent of depth of sinkage—the Gerstner-Bernstein proposition equating the work expended in overcoming rolling resistance with that done in compressing the soil beneath the wheel was generally accepted, but might lead to statements of rolling resistance of varying complexity according to the values assigned to various soil functions.

Fig. 5 of the Paper did not make it clear to the speaker why a tyre of double width should have four times the load-carrying capacity for the same sinkage ; other things being equal, he did not think this was so. However, in practice increasing width of wheels was often accompanied by an increase in length of ground contact, and the form of the contact area probably became more efficient as a bearing area. It might be noted that the S.M.M.T. rating of carrying capacity, based on deflection on hard ground, was roughly proportional to the square of the nominal section width as shown in Fig. 21. Therefore a tyre of double width could be said to have intrinsically quadruple carrying capacity, but it did not follow that sinkage would be constant under these conditions if ground contact length were not increased.

There was much evidence of the value of diameter rather than width. Coulomb's formula ($R = \frac{Wx}{D}$ —where R is rolling resistance, W vertical load, x a constant depending on the nature of wheel and surface, and D the effective diameter of the wheel) referred to the rolling of hard wheels on hard surfaces ; though based on only a short series of experiments,[9] it conformed to statical analysis of the forces involved and was confirmed by Morin in more rigorous experiments.[10] On deformable soil, rolling resistance is not proportional to D^{-1}, but McKibben's experiments (summarised in Fig. 6b) show a value of the exponent close to -1 for a wide range of conditions.[11] Wright, Wilson and Hamblin[3], and Nuttall[12] had shown large diameter wheels to be advantageous. As the author had said, cost was one of the main factors making designers adopt wheels smaller than might be theoretically desirable. Fig. 22, based on S.M.M.T. ratings, showed that cost of tyre and tube (approximately proportional to weight) increased with diameter but decreased with section width for a given load-carrying capacity.

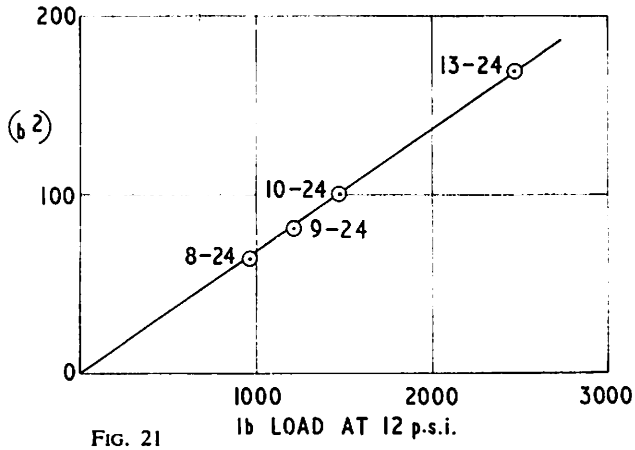

FIG. 21

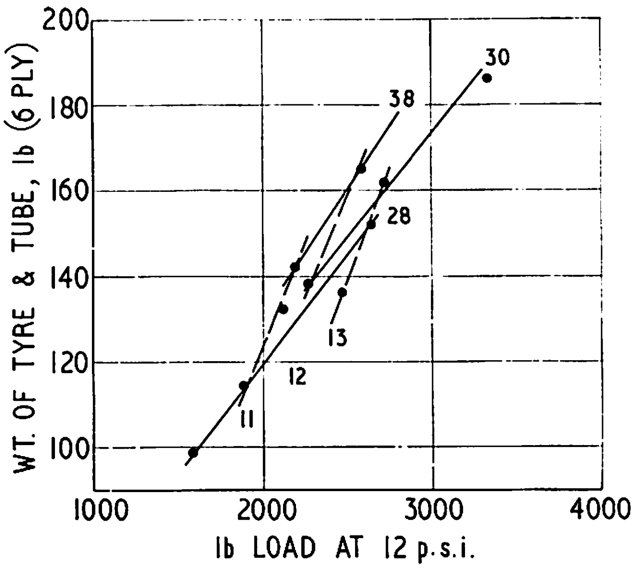

FIG. 22

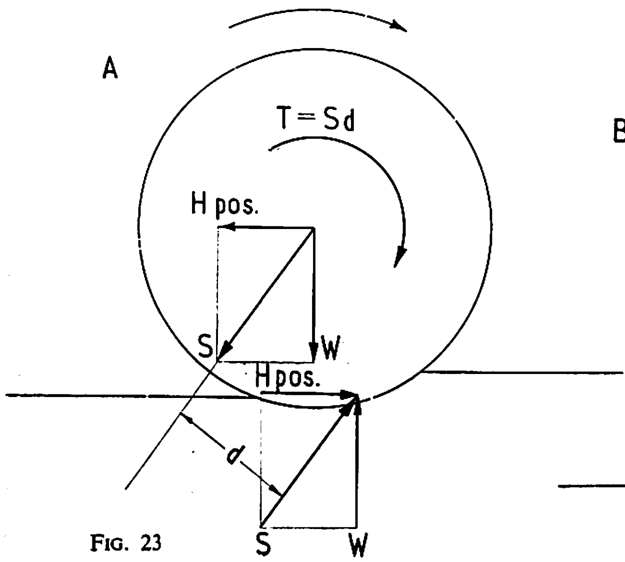

FIG. 23

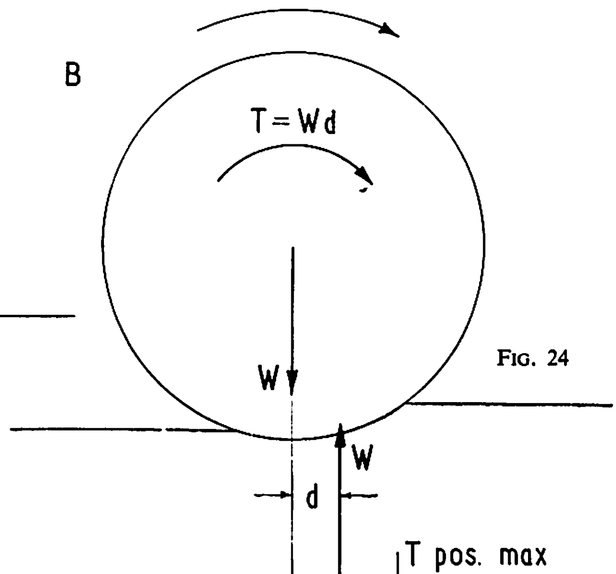

FIG. 24

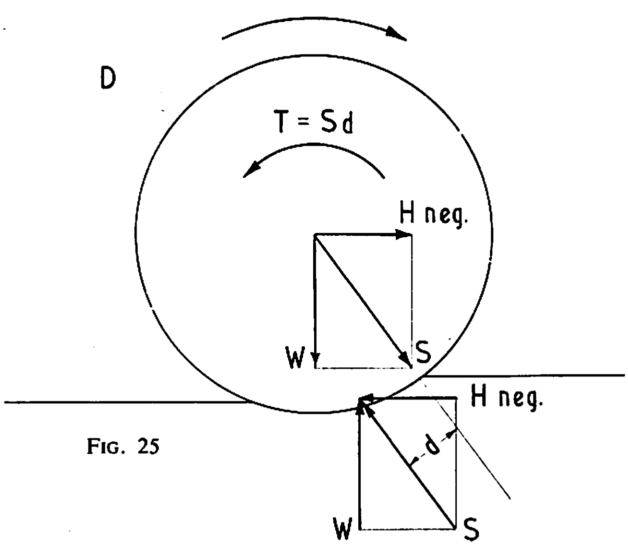

FIG. 25

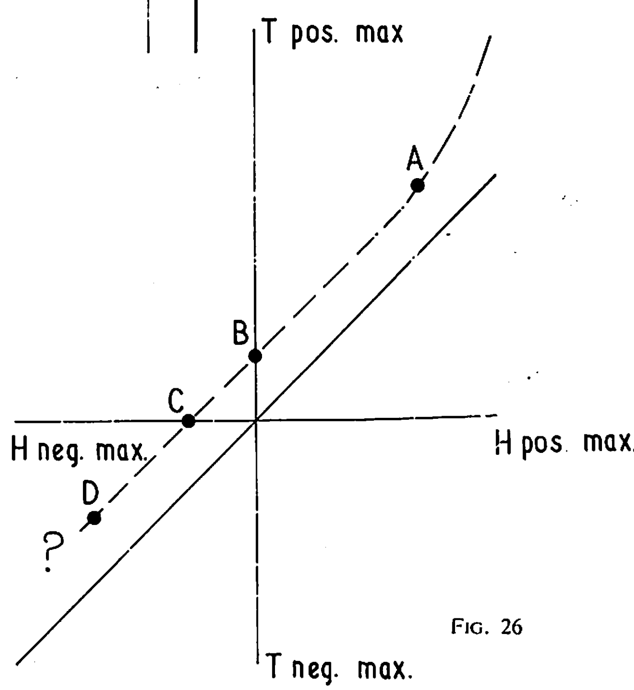

FIG. 26

In the Paper driving and non-driving wheels had been mentioned separately, but the speaker considered it important to regard the non-driving wheel as a special case of the driving wheel with zero horizontal force. Fig. 23 showed the general case for a tractor driving wheel. The resultant soil reaction S had a horizontal component H pushing the tractor forward and a vertical component W supporting the tractor. The couple set up by the tractor and soil forces on the wheel, which were displaced by the offset d was equal and opposite to the driving torque T (the speaker regretted that he had inadvertently used the symbol T in his illustrations for torque when it had already been used for tractive force by the author). When the horizontal force was zero, a driving torque was required to overcome the rolling resistance which was, of course, manifest in the forward shift of the soil reaction due to soil compression and tyre hysteresis (Fig. 24). It might be noted that the forward shift was equivalent to the quantity x in the Coulomb rolling resistance equation. Further reduction of the horizontal force to the negative quantity just necessary to overcome rolling resistance produced the case illustrated by Fig. 4, with the line of action of the resultant soil reaction passing through the centre of the wheel at zero driving torque. Finally, application of a negative torque, as in a wheel-driven machine or braked wheel caused the negative horizontal force to be increased (Fig. 25). In Fig. 26, torque T was plotted against horizontal force H. The effect of rolling resistance was manifest in the displacement of the curve from the straight line through the origin, and clearly rolling resistance could only be defined satisfactorily at points B and C (corresponding to Figs. 24 and 4). It was often convenient to express it throughout the traction range in terms of the difference between actual and ideal horizontal force, but that required knowledge of the effective rolling radius of the wheel throughout the traction range.

The input and output work of a wheel could be expressed with certainty and thus an efficiency value stated with conviction. The sources of the inefficiency could, however, only be apportioned between slip and rolling resistance (in which the speaker included the soil excavation losses) if satisfactory definitions of no-slip distance and consequently effective rolling radius could be agreed, for those quantities were at best indeterminate and might even be regarded as mere abstractions.

The exact value of distance travelled at zero slip, was indeterminate. In work with the N.I.A.E. Single-Wheel Tester, including the strake experiments[2], no-slip distance had been defined as that travelled per revolution of zero horizontal force, and effective rolling radius was assumed to be constant for each wheel in constant soil conditions. The definition was controversial, but they would continue to use it until convinced otherwise ; at least it gave a fairly constant value of rolling resistance over a wide range of horizontal force values. It might be impossible to reach a theoretically satisfactory definition of effective rolling radius, and it was thus possible that future wheel research might take wheel losses as a whole instead of separating them into slip and rolling resistance.

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In reply, THE AUTHOR said that although he could not fail to agree with Mr. Bailey, his comments were gently leading them to a more scientific approach to the problem than had been attempted in the Paper. It was a case not of a difference of opinion, but of Mr. Bailey going a little further than the author had been inclined to go. That explained the author's apparent omission to give full expression for both soil shear resistance components, the frictional resistance and the cohesive resistance. Rightly or wrongly, he had avoided those matters for the sake of clarity. He had treated the factors separately, but he had said in the Paper several times that soils were a combination of the two factors.

In his comment on slip relationships he had more or less followed the work of Bekker. Mr. Bailey had declared that he had said that there was a direct proportionality between sinkage and rolling resistance. He did not think he had stated it quite in that way. If he had done so, he had not been accurate because although they could agree that there was a proportionality, it would be very difficult to agree on the parameters of the depths, on whether they were physical depths, units of pressure, or something else. However, they could assume that the proportion was roughly direct, and in doing so they would not make any great error.

The author had followed Bekker's work on tracks when dealing with widths of tyre and the relationship to load-carrying capacity. Bekker had based himself on formulæ developed in civil engineering where the load which a given wall could support standing on the ground was proportional to the square of the width. That might not be quite accurate for tyres, but it was the nearest approximation they could get.

Mr. Bailey's last slide had shown that spade lugs produced a rolling resistance much higher than that of a pneumatic tyre. On the other hand, at the same tractive effort the slip with the spade lug was much reduced.

MR. B. W. J. LACEY, Dunlop Rubber Company, said that it was significant that the data provided by tyre companies was always for performance on hard soils. It was extremely difficult to provide data on soft soil conditions. Tyre movement was very important and they could study the movement of soil and the movement of tyres and discover some of the fundamental properties of soil.

From time to time attempts had been made in this and other countries, notably America, to produce a sort of standard test bed on which standard testing could be undertaken and thus obtain reliability of figures and some consistency. However, it had been found very difficult not only to produce a standard soil bed, but to maintain it in a reasonable condition.

The author had mentioned a very interesting characteristic of a tyre—wrinkling. He had suggested that there was a need for a tyre which would work at lower pressures and higher deflections than was now possible. Wrinkling was a very involved subject. Some tyres would wrinkle slightly with the application of static load, particularly some of the early aeroplane tyres under torque. Usually that deflection was between 25% and $33\frac{1}{3}$%. On the other hand it was difficult to make some tyres wrinkle, even under very high draw-bar pulls. The opinion which they had formed was that harmful wrinkling did not occur with any combination of load deflection and pressure which was required to suit reasonable soil conditions. If higher deflections or lower pressures were considered desirable then side wall flexing, if it were a plain, straightforward flexing without wrinkling, would be such as to cause the tyre to fail immediately. In other words, if there were something very abnormal in the soil which had to be worked, much greater deflection or lower pressure was the answer.

They had noticed a trend towards semi-circular sections for continental tyres and in this country. It was an interesting change and one which could lead to repercussions, some beneficial, some harmful. It helped the stiffening of side walls, and in that respect might assist in a solution of the wrinkling problem, if wrinkling were the major problem. It could also aid traction, as the author had said, in lighter soils, and probably produce slightly greater compaction where the soil could be compacted to advantage. However, in certain other conditions it would be a serious disadvantage. On the heavier soils experienced in this country one needed considerable depth of tyre at the edges to get a bite in the heaviest of ploughing conditions, particularly when working with one wheel in the furrow as was common in this country.

The author had accurately described the essential features in the tread bars of a tyre and had pointed out that extra deep bars which could be very efficient on very heavy soils wore out very quickly on roads. Wear on roads was a serious problem for the ordinary agricultural tyre with standard depth of bar. To provide good traction and good road wear it was necessary to reach a compromise. In present-day conditions of work in this country one had to cater for about 20% to 25% operation on hard road surfaces. A figure as high as 70% had been quoted by a German colleague. Did the author have any views of the time a tractor spent on road work, particularly in continental areas ?

That again raised the question of tread-bar proportions. The author had said that one had to consider modifications of the standard bars to suit certain types of soil. On the Continent for many years it had been the practice to have bars which were rather shallower, closer pitched and broader. That was for generally light soil conditions where there was a great deal of road work. Although it had recently been changing, the trend on the Continent had been to cater for road work. Overseas conditions could often be satisfactorily met by a tread which in this country would be regarded as usable for road and light land work.

It was obvious that the author had made a very close study of tyres. The speaker greatly appreciated the fact that he had dealt with their limitations in a kindly manner. However, he had exposed the challenge in pointing out that in some cases efficiency was as low as 40%, and in others only 80%. However, there was bound to be that gap for some time. Nevertheless, everybody could be assured that tyre designers were working very hard to raise that lower figure to something more reasonable, but because of the tremendous variability in soil it would not be a very easy job.

In reply, THE AUTHOR said that he wanted to put in a good word for the N.I.A.E. While it was a very lengthy process to collect the necessary experience and data from the various types of field work, that must ultimately lead to better and closer equations than the American way in which one used a trough inserting a mixture which was compacted to a certain degree and on which tyres were then tested. With that method there was no allowance for vegetation so that although those tests were accurate, they were somewhat academic.

He had been interested to hear that tests had drawn conclusions about closed centre tyres which were contrary to the statements which he had made in the Paper. He bowed to Mr. Lacey's experience on that.

MR. A. R. REECE said that Mr. Senkowski's Paper has to be welcomed because it was one of the first signs of an awakening interest in the relationship between the tractor and the soil among tractor designers. Tractor designers in general appeared to be exclusively concerned with the Mechanical Engineering aspect of their work. The result of this was to be seen in the present-day situation in which tractors run on wheels which have not changed substantially during a period of several thousand years or on tracks which have changed not at all since they were invented by Edgeworth in 1770.

This situation was partly due to the fact that the problems involved were complex and, although very many agricultural and military engineers had studied these problems in the past century, progress was very slight until quite recently. A major step forward had been made by Col. Bekker, whose ideas formed a coherent picture of the soil and wheel or track relationship. Bekker's ideas had won considerable acceptance in the U.S. Army and elsewhere and he now had most impressive facilities with which to pursue this study.

The basis of Bekker's approach was that the soil could be characterised by seven constants which are obtained from two tests made on the soil. One test measured the resistance that the soil offered to vertical deformation, and the three constants involved were obtained from forcing two small footings into the soil and recording the pressure-sinkage curve. The second test measured the relationship between soil deformation and horizontal applied stress. The measurements were obtained from twisting a loaded anulus which was in contact with the soil surface, and recording torque against twist. Four constants characterise the results, two of which are the familiar c and ø.

The infoımation from the sinkage test could be combined with the vehicle constants to predict the rolling resistance. The information from the shear test could be combined with the vehicle characteristics to predict the relationship between its gross tractive effort and its slip. The net vehicle performance was obtained from the idea that net tractive effort is equal to gross tractive effort minus rolling resistance.

Mr. Senkowski's suggestion that the carrying capacity of a wheel is in some way proportional to the square of its width was questioned by Mr. Bailey. Bekker proposed and uses the following equation in order to relate sinkage to load per unit area or ground pressure.

$$P = \left(\frac{K_C}{b} + K_\phi\right) Z^n$$

In this formula Kc, K_ϕ and n are constants describing the particular soil. Z is the sinkage and b the width of the contact area. It is clear from this formula that the effect of width can only be to reduce the carrying capacity of a given area for a given sinkage.

It is interesting to note that the theoretical approach of Colonel Bekker's appears to be fruitful in terms of new concepts of vehicle form. In his laboratory I have recently seen radical departures from the conventional ground drive equipment—such novel devices as the space link track, the hubless wheel and the triangular pneumatic tyre.

MR. FRANK MOORE, Essex, said that in his county, with heavy land farming, a major problem arose when they reached the limits of adhesion for pneumatic tyres. A number of farmers would not permit the use of pneumatic tyres because of wheel slip and the destruction of soil structure. They insisted on using steel wheels whenever a crawler tractor was not available. The type of steel wheel varied tremendously and there were conventional types such as the spade lug and skeleton wheel. Could the speaker recommend any particular type of steel-lugged wheel to give the greatest possible adhesion combined with the lowest rolling resistance on heavy clay soils ?

In reply, THE AUTHOR said that his experience with steel wheels was very limited. Roughly speaking, wheels giving the best tractive effort would have the biggest rolling resistance. That applied to a traction augmenting device. That was a statement of a truism, but it allowed him to escape the question.

MR. CATCHPOLE said that he had done some work on trying to determine the optimum angle for the strake and he had concluded that it was best to aim at getting a strake which would leave the ground as early as possible, the soil-compressing effect as the strake entered being able to be ignored. He had exhaustively tested a number of types of lug, but the type he had now worked well on a wide range of wheels. The augmenting devices used when conditions were extreme did churn the soil to some extent, but the working was slow compared with traction effort produced.

MR. BAILEY said that they had published a test report on a very heavily-lugged steel wheel. They had done no research work as such on the lug angle. Their general experience was that if traction was increased, rolling resistance was increased more or less in proportion in clay soil, while on sandy soil it increased only a fraction. They were looking forward to testing Mr. Catchpole's wheels and trying out his optimum lug angles.

COL. PHILIP JOHNSON said he was glad that the author did not attempt to treat the subject from a purely scientific standpoint, but obviously based his conclusions on a wide practical experience. He regarded pure research, with no other object in view than increased knowledge, as of inestimable value, but did not, however, consider that the adhesion of pneumatic tyres to the soil surface conditions throughout the world was a practicable subject for scientific conclusions of value. On a pure research basis with no stated objective by all means let study be devoted to soils ; but with the stated objective of laying down scientific data on which to design the vehicles to operate over the land surfaces of the world, he regarded such efforts as quite impracticable, unless on a very restricted scale for a specific purpose in conditions where the soil and its surface were reasonably static and uniform. Soil surface conditions were infinite in number and variable in time, often from minute to minute.

One point not touched on by the author would, he hoped, be dealt with in Papers to come—*i.e.*, Four-Wheel Drive and its remarkable performances. He also hoped for some future discussion on the difference between unavoidable or permissible slip and spin. The former should be limited to a maximum of 10% for efficient work, and the latter was, by shock loading, responsible to a large extent for excessive wear on tyres, and even the transmission, and also by " smear " for detrimental effects on the land.

MR. D. MANBY, N.I.A.E., said that he had been surprised when Mr. Lacey had said that the effects of normal deflection of the side wall could be as serious as wrinkling. From work done ten or twelve years ago on side-wall wrinkling it was always thought that it was the acute wrinkling due to the transmission of torque which caused tyre wall destruction. There had been mention in the Paper of 100% fill, 95% fill and 75% fill. So far as reducing wrinkling "100% fill was good, but 95% and 75% had little, if any, effect. If one plotted deflection/load curves on tyres with various percentages of water fill, the shape of the 100% fill curve was very different from the others—markedly so. In field tests it had been found that one could run 100% filled 11–36 tyres at a pressure as low as 7 p.s.i., developing pulls of 3,800 lb., or thereabouts. A practical advantage, which is not usually recognised, is that if one wants to use a heavy-mounted implement, which would grossly over-deflect the tyre on the headland if air inflated to normal pressures and deflections when the implement is in work, one can very often get round the difficulty by 100% filling. The tyres can then be run at a deflection of 30% or so in work, thus ensuring maximum adhesion when the implement weight is not on the wheel, but the tyres will not over deflect on the headlands.

(continued from page 26)

have had greater opportunities at school in the physical sciences and therefore not be aware of your own potential in such subjects as botany and geology. Ask your school masters!

Whichever you choose, engineering or agriculture, you will have to decide whether you have the ability and can afford the time (three or four years) to read for a university degree. Do not be too worried about expense; most County Education Authorities and other public bodies are prepared to award scholarships to those who have sufficient ability. The thing you do need to worry about is that most universities require G.C.E. at "O" level with a minimum of five subjects including at least two, usually more, "A" levels. Physics, mathematics, chemistry and English are particularly important.

If, for any reason you cannot go to a university then there are numerous colleges which train for diplomas and certificates in engineering and agriculture. These awards are generally made by professional bodies such as the Institution of Mechanical Engineers and the Royal Agricultural Society and are held in high esteem by the industry. The method of training is usually flexible and varies from a two-year full-time course at a residential college to evening classes and sandwich courses while carrying out a job. Many firms are in fact prepared to release trainees for one whole day per week to attend a technical college.

I mention the arrangements for theoretical training first because most universities and many colleges have considerable waiting lists. You should therefore get your name down. It is, however, also essential to receive at least one and frequently more years of practical training and this often fits conveniently into the waiting period before commencing your academic training. Depending upon which branch of the industry you wish to enter, you should either work in an engineering firm (not necessarily manufacturing agricultural equipment) or on a mechanised farm. You will of course expect to be paid at normal rates for your age during this period.

At the end of your basic training, whether degree or diploma, and whether engineering or agriculture, it is highly desirable, though not always essential, that you should receive a post-qualifying training in agricultural engineering. A small number of graduates, particularly those who intend to go on to research or teaching, may be able to proceed to a higher degree at a University. Durham University has a special course leading to an M.Sc. in agricultural engineering. The majority, however, would be better off taking the Institution of British Agricultural Engineers' Diploma (the N.D.Agr.E.)* which is a one-year course leading, after further experience in the industry, to corporate membership of the Institution. On this course you would concentrate on that branch in which you had *not* received your basic training. For some years the Institution of British Agricultural Engineers has stressed the need for a College devoted solely to the teaching of agricultural engineering. The Minister of Education has recently announced that such a College is to be founded soon and, meantime, training can be obtained at other Colleges which are mentioned in the I.B.A.E.'s Education and Training Leaflet. There are scholarships available for these courses too. The details relating to methods of training for the industry are given in the "Handouts" you have been given.

CASE HISTORIES

In order to show you the sort of thing you might expect to be doing during the early part of a career in agricultural engineering the Institution of British Agricultural Engineers has prepared a few details on the progress of actual people who have entered the industry during the past few years.

SUMMING-UP

I hope I have succeeded in putting before you a picture of an expanding industry abounding in opportunities for men of ability and enthusiasm. Before finishing, I want to say a special word to those of you who, besides earning a livelihood, seek the satisfaction of feeling that you are making a real contribution to the welfare of mankind. There are a number of such occupations. Medicine is one, farming is another, and giving the farmer the best possible tools to do his job is every bit as important as either. If I were asked whether I would rather have designed the Forth Bridge or developed the first combine harvester, I should choose the latter.

APPLICATIONS OF ELECTRICITY TO AGRICULTURE

by P. FINN-KELCEY, A.M.I.E.E., A.M.I.B.A.E.

A Paper read at an Open Meeting of the Institution on 17th February, 1959

POWER

ELECTRIC motors were in production, mainly for industrial uses, well before the turn of the last century, and it is interesting to note some of the trends in design that have been followed since that time. New magnetic materials have been developed and improved, new wire and rotor insulations have become available, and very great advances have been made in reducing the bulk and weight of motors of a given horse-power output. For many years, when linehsafting was the order of the day in most industrial plants, a smaller number of relatively large motors was required. Now, however, the fashion has changed and individual motors forming an integral part of the driven machine are very much in vogue. To-day, by far the greatest number of motors turned out is in the 3 to 5-h.p. range, and within that number the vast majority of the motors are of the squirrel-cage type. With advances in design, leading to more efficient cooling, one manufacturer claims that a particular motor frame size that 50 years ago could only accommodate 3 phase a 7½-h.p. motor would now accommodate a similar 40-h.p. machine.

During the spurt in development following the first world war, ball and roller bearings were introduced in place of the oil ring bearings that had previously been used, and this alone resulted in a considerable cheapening of production costs and the corresponding lightening of the whole assembly. The introduction of a system of radial ventilation as distinct from the previous axial form, together with more improvements in the magnetic materials, brought about further lightening of the motors and enabled the designers to produce a much sleeker machine.

The heat losses that are generated in a motor will depend on the magnitude of the load that the motor is required to give. This heat is dissipated principally by the ventilating system within the motor, but the surface area of the carcase also plays a part and the materials used in the motor construction have some effect upon the rate of dissipation. When a motor starts up from cold and is put on load, its temperature will rise until a point at which the temperature becomes steady—that is, when the cooling system can dissipate the heat at the same rate as it is being produced. The steady temperature to which the motor settles down under these conditions is then plotted against the load and a graph obtained by varying the load. From this graph the continuous rating of the motor is determined, as the maximum safe working temperature is well known for each inidividual class of insulation. (Fig. 1.)

Dimensions of three-phase electric motors with ventilated enclosures are now standardised by the issue of British Standard Specification 2,960, 1958, and this publication sets out much useful information for intending purchasers, dealing as it does with foot-mounted motors, flange and skirt-mounted. For special duties, however, the designer still has freedom of action, and by manipulation of various factors under his control can design motors for specific duties and for positions where a standard-type motor cannot be accommodated. For instance, by increasing the magnetic flux density in the air gap, the copper content of the motor is reduced and the iron content increased, and by this means the overall diameter of the machine can be reduced at the expense of an increase in length. This alteration of design results in a high maximum torque, but also a high starting current. Conversely, if the magnetic flux density is decreased, a higher copper content results and this requires wider and deeper slots to contain it. Thus a large diameter and foreshortened motor results. The characteristics of such a machine would be low maximum torque accompanied by low starting current.

It frequently happens that the type of motor finally selected for duty on a piece of agricultural equipment is dictated rather by the limitations of the starting current than by the true mechanical characteristics of the load. Table I shows the starting current and starting torque characteristics for various types of single-phase motor and also indicates the type of starter that may be used.

Table I

Rated Motor H.P.	*Type of Motor.*	*Starting Torque. Full Load Torque.*	*Starting Current, Full Load Current.*	*Type of Starter.*
Fractional horse-power	Capacitor-start squirrel-cage	1 or 2 to 4	3 or 3 to 4	Direct
	Split-phase squirrel-cage	1·5 to 2	6 to 7	Direct
”	Repulsion-induction	2 to 2·5	2 to 2·5	Direct
1 to 5	Repulsion-induction	3 to 3·5	3 to 3·5	Direct
1 to 50	Capacitor squirrel-cage	0·8 to 2·0	3 to 5	Parallel-series + capacitors
1 to 50	Capacitor squirrel-cage (special)	0·5	1·25 to 1·6	Double parallel-series + capacitors
1 to 50	Split-phase squirrel-cage	0·25	2 to 2·5	Resistance
1 to 50	Slip-ring split-phase	0·3	1· to 15	Resistance (in rotor winding)
1 to 50	Slip-ring capacitor	1 or 1·5	1·5 to 2 or 2·25 to 3	Parallel-series with capacitors

Since the last war, manufacturers have made further strides in the performance and general appearance of their motors, and in particular national agreement on the method of motor rating has been achieved. Until the issue of the British Standard Specification 2,613 in 1957, motors of 50-h.p. and below had been rated on the load-plus-overload system, and this often led to confusion in the minds of purchasers. The new specification, however, introduces the term " continuous maximum rating," and if the voltage and frequency conditions on the motor name-plate are complied with, then this motor may be operated for an unlimited period at the specified load conditions without damage to insulation due to an excessive temperature rise. (Fig. 1.)

A short-time rating may also be quoted for one hour or half-an-hour, whichever is appropriate, and this latter figure indicates the time for which the machine can operate under the up-rated conditions, starting from cold. The permissible temperature within the motor windings is entirely governed by the type of insulation that is used, and with impregnated cotton or enamel covered wire, which is commonly called Class A insulation, the limiting temperature is 105° C. Allowing a safety factor of 15° C., mainly because it is not always possible to measure the temperature at the hottest point within the windings, and also allowing for the fact that the motor may have to run in an ambient temperature of 35° C., this leaves 55° C. as the permissible temperature rise due to the machine operating on load. Thus, if it were found that for a certain motor, running on prolonged test and developing 5-h.p., the winding temperature reached, but did not exceed, a figure of 55° C. above the ambient temperature, the continuous maximum rating (C.M.R.) of this machine would be stamped as 5-h.p. on the name-plate. Conversely, if the duty foreseen involved some overloads, this same machine might be rated down to 4½-h.p. c.r.p.o.—that is, continuous rating permitting overloads.

In more recent years a new group of wire enamels, based on polyurethane or epoxy resins, etc., has come into general use, and because of the better temperature-resisting properties of these materials working temperatures can be increased. The whole of this group has now been brought together to form Class E insulation, and the benefits immediately apparent are that the permissible temperature rise, previously 55° C. with Class A insulation, has now been stepped up to 65° C. for Class E. The practical effect of this new material is such that one size smaller in the standard 3 phase motor frames can now be used with this material than was previously used with Class A insulation. The standard motor frame sizes have been laid down by the British Standards Institution as 1, 1½, 2, 3, 5, 7½, 10, 15, 20, etc., and it will, therefore, be seen that the frame size for a 10-h.p. 3 phase motor with Class A insulation will now accommodate a 15-h.p. unit if Class E insulation is used in its place.

Types of Motor Enclosure

In the British Standard Specification 2,613, 1957, there are listed no less than 20 forms of motor enclosure, but for common use in agriculture only the following need be considered :

1. *Screen Protected :*

In this type all ventilating openings in the frame and end shields are protected with wire screen, expanded metal or perforated covers, having apertures not exceeding ½ sq. in. in area, but not less than 1/50th of a sq. in.

2. *Screen Protected with Fine-Mesh Covers :*

This is similar to the type above, except that the openings are smaller than 1/50th sq. in. in area, but because of the frequent clogging of the small openings, this type of motor is rated as though it were a totally-enclosed machine.

3. *Drip-proof :*

In this type the ventilation openings are so protected as to exclude falling water or dirt.

Table II

COMPARATIVE DATA FOR 5-h.p. THREE-PHASE MOTORS

Motor speeds (syn.)	3,000	1,500	1,000	750	600	500	375
Relative cost	98%	100%	125%	145%	175%	200%	310%
Number of poles	2	4	6	8	10	12	16
Efficiency	84%	85%	84%	83%	82%	81%	79%
Weight	85%	100%	130%	160%	200%	240%	440%

Table III

PERFORMANCE OF TYPICAL 5-h.p., 1,500-r.p.m. MOTORS AND RELATIVE COSTS, INCLUDING STARTER

Phase.	*Motor Type.*	*Starter Type.*	*Efficiency* %	*Starting Conditions as % of Full Load.* *Torque.*	*Current.*	*Cost* %
3-phase	Cage	Direct	85	175	600	100
3-phase	Cage	Star-Delta	85	45	200	105
3-phase	Cage, high torque	Various	85	80	200	150
3-phase	Slip-ring	Resistance	82	100	120	225
1-phase	Cage	Split-phase	78	25	200	170
1-phase	Cage	Time delay	82	100	400	215
1-phase	Cage	Time delay	82	50	125	215
1-phase	Slip-ring	Split-phase	76	30	125	275
1-phase	Slip-ring	Capacitor	79	100	125	280

4. *Pipe Ventilated :*

Machines of this type are generally used in dusty atmospheres and they draw, and sometimes exhaust, their ventilating air by means of pipes taken through the wall or roof to a source of clean air.

5. *Totally Enclosed :*

As its name implies, this type of motor has no ventilation openings, but it must not be assumed that it is either flame-proof or water-tight.

6. *Totally Enclosed, Fan Cooled :*

This motor is fitted with an external fan secured to the motor shaft and this blows air over the casing of the motor, and in some types through sealed air passages within the motor carcase.

7. *Flame-proof :*

This form of motor is designed principally for use in mines, but is also installed in some mills where it is considered that the dust of grass meal, air-borne in an improperly ventilated building, might be explosive in nature.

Machine Drives

The cheapest, simplest and most efficient form of drive is, of course, a direct one, and if the motor can be selected so that its speed is the same as that required for the driven machine, then it may be possible to mount the latter directly on the shaft or on one of the standard forms of shaft extension. Alternatively, a flexible coupling may be used and, although slight misalignment of the two shafts can be taken care of in this form of coupling, its life will be much increased if the shafts are carefully aligned centre to centre. Where V-rope drives are necessary, the type of load that is required should be classified under one of the following headings, and due allowance made in selecting the driving motor. It is not always realised that the overall efficiency of a V-rope drive is not 100 per cent., and the following allowances should be made. For centrifugal pumps and light, well-balanced fans, a duty factor of 1·2 should be used ; that is, the continuous maximum rating of the motor should be 1·2 times the rated duty for the driven machine. For mixers, light conveyors and circular saws, the factor should be increased to 1·3. For heavy fans, compressors, vacuum pumps, heavy conveyors and elevators, hoists and crushers, the factor should be 1·5.

LIGHT

The applications of light in many branches of agriculture are as yet few and relatively unimportant, but in poultry keeping the effects of light in regulating day-length for laying hens is widely recognised, and supplementary lighting in winter time is now common practice for winter egg production. The hen normally reaches her natural peak of egg production in March, when the natural day-length has reached a value of 13 to 14 hours, and by the simple expedient of supplementing short winter days with artificial light to a total of 14 hours, increased egg production is easily realised. The first theories on this point were that as the hen had a longer working day she could consume more food and was thus in a position to lay more eggs. This simple theory, however, was considerably upset by work carried out by a Swiss scientist, Staffe, who found that by giving short flashes of high intensity of light to the birds during the normal winter night he was able to get a comparable increase in egg production to that resulting from supplementing the normal winter day to 14 hours. In Staffe's experiment, the birds only had the short 7 to 8-hour winter day in which to collect their food, but yet they laid as well as did those that had 14 hours for feeding.

The Poultry Department of Reading University and the Electrical Research Association jointly carried out a series of experiments to confirm Staffe's findings, and they found them to be substantially correct. Over a series of winters, further experiments were tried, always using tungsten lighting, but varying the intensity of the light, the duration of the flashes, the number of flashes, and the timing of the flashes relative to the natural dawn. The first theory that appeared to emerge from this work was that the total light quantity administered was the controlling factor—that is, the increase in egg production over that of birds receiving no additional light was in proportion to the quantity of supplementary light (measured in lumen hours) that the birds received. It did not appear to matter whether this light was administered at high intensity for a short total period of flashing or at lower intensity for a longer one. On closer investigation, however, and following a further winter's work, it is now believed that the important factor is that the " effective " day-length should be 14 hours. This is, perhaps, best explained by saying that if any reasonable quantity of light is administered to the birds, no matter in how many flashes or of what intensity, it will be most effective if the first flash appears approximately 14 hours before the natural hour of dusk. In other words, if the bird is given an artificial dawn with intermittent flashes from then until the natural dawn, it is, in fact, enjoying a 14-hour day and will adjust its egg production accordingly.

The National Institute for Research in Dairying, again in collaboration with the Electrical Research Association, have carried out a preliminary series of tests on the effect of day-length on fattening pigs. Initially, at least, this line of investigation has not shown itself as promising as that with the hens. In the experimental set-up, four comparable groups of pigs, four in each, were housed in four separate and light-proof compartments. All groups were subjected to the same conditions of temperature, relative humidity and air change, the only difference between the groups being that each had a different tungsten lighting treatment. The pigs were kept in these compartments from weaning at eight weeks until they had reached bacon weight. The lighting regimes given to the four groups were as follows :

- Group 1. 24 hours' lighting per day.
- Group 2. No lighting at all.
- Group 3. 14 hours of light and 10 hours of darkness per day.
- Group 4. 10 hours of light followed by 10 hours of darkness.

This last treatment was included to see whether the pigs could make the same weight increase in a 20-hour day as the others would in 24 hours. The surprising result from this initial test was that there was no significant difference between any of the groups, and their total live-weight gains and conversion ratios were almost identical.

Many other interesting lines of research connected with the influence of light on animals will come to mind, and no doubt our knowledge in this direction will be increased year by year, but equally interesting investigations have been made into the effects of light on plants of many kinds. This line of research can be divided into two distinct divisions—namely, studies of the behaviour of plants under normal daylight, plus supplementary artificial light, and on the other hand the behaviour of plants under artificial light only. So far, no artificial light source has yet been devised that will supply precisely all the conditions obtaining in natural sunlight. The three principle parts of the spectrum that have notable effects on plant growth are the red light, which appears to give the greatest increase in plant material ; the blue light, which seems essential for the proper shape development of the plant ; and the near infra-red light, which has a pronounced " drawing " effect. For good plant growth, therefore, it seems that an artificial light source should emit a high proportion of red light, some blue, and none of the near infra-red, and care should be taken to see that the red portion of this light does not contain the far infra-red which would have an undesirable heating effect. It should be remembered in measuring the output of various lamps, or light sources, that the sensitive element in the form of light meter normally used has nothing in common with the light sensitive portions of a plant and, therefore, instead of attempting to measure the light output at the level of the plant in lumens per sq. ft., an absolute unit of power such as milliwatts per square metre should be used.

For bulb forcing in a darkened building, where relatively low intensities of light are required, ordinary tungsten lamps are found to be quite satisfactory. By mounting 40-watt lamps about 12 ins. above the growing tip of the pre-treated bulb, two lamps being required per sq. yd. of bench, tulips and daffodils can be made to bloom satisfactorily with 12 hours of artificial light per day. Several tiers of bulbs can be arranged in a suitable darkened building, and if, in addition, the standard of heat insulation of the building is satisfactory, then these lamps will help considerably towards maintaining an air temperature of the order of 60–65° F. This method of forcing bulbs and flowers at times of the year when blooms are scarce is well established, and those who have practised this form of culture, often in redundant farm buildings, have found it a success commercially. The conventional glasshouse, by its very nature, is an extremely costly structure to heat, and the saving of fuel in a well-insulated and darkened building would more than compensate for the cost of artificial lighting. Research into the possibilities of growing other plants entirely under artificial conditions is now proceeding, and the prospect of etxending the usefulness of this form of culture is most encouraging.

The application of supplementary light to plants during the winter months when the intensity of daylight is low, and the days are short, is a further interesting study. Many commercial growers are already using this form of lighting for tomato and cucumber seedlings, and provided that the glasshouse temperatures are carefully maintained, quite startling results are achieved in earlier fruiting of the plants. After pricking out, tomato seedlings are irradiated for three weeks and by this means are ready for planting out a fortnight before similar plants that have received no supplementary light.

Table IV
SUMMARY OF LAMP DATA

Lamp.	*Type.*	*Predominant Colours.*	*Amount of Infra-Red.*		*Control Gear Required.*	*Suitable Application.*	*Comments.*
			Near.	*Far.*			
Tungsten	Incandescent	White	Appreciable	Considerable	None	Bulb forcing, control of flowering dates	Cheap, too much infra-red. Low intensities only
Sodium	Discharge	Orange-yellow	None	A little	Transformer + capacitor	None	High capital cost
Fluorescent Tubular	Discharge	White or coloured	None	Very little	Choke, capacitor + starter switch*	Daylight for growing rooms	Low intensity. Too costly for glasshouse work
Mercury	Discharge	Blue-green	None	Appreciable	Choke + capacitor	Supplementing winter daylight	Insufficient red and excess infra-red, but economical
Mercury-Fluorescent	Discharge	Blue-green + a little red	None	Appreciable	Choke + capacitor	Supplementary lighting and perhaps replacing daylight	High red content, useful, but high first cost
Mercury-Tungsten	Discharge + incandescent	Blue-green + white	A little	Appreciable	None	Supplementary light	Inexpensive high intensity source, but slight excess of near infra-red

* One alternative circuit for 40 watt lamps employs a tungsten ballast lamp, with reduced efficiency.

The effect of this accelerated development is shown up in the earlier yielding of fruit, and an increase of more than ½ lb. of fruit per plant has been picked during the first month of harvesting, when, of course, the price is at its highest. Under such conditions, the initial and running costs of the lighting equipment can be repaid in a single season. In the present state of our knowledge the standard 400-watt mercury discharge lamp appears to be most suited to this duty, and large numbers of them have been installed on progressive commercial holdings.

Chrysanthemum growers have now turned their attention to light treatments that can be used not only for delaying the flowering of chrysanthemums until the more favourable Christmas market,, but to extending the flowering period to the full twelve months of the year. These " manipulations " can be done quite satisfactorily with ordinary tungsten lighting, and a well-known chrysanthemum grower in Sussex has an installation in his glass houses totalling 280 kW. ; *i.e.*, 2,800 lamps of 100 watts each. These are mounted some 4 ft. above the plants at 6 ft. intervals along the beds. Chrysanthemums will normally commence to flower when the length of the night becomes greater than a certain value. Thus, through lengthening the day by giving artificial light from just before dusk, flowering can be delayed at will, and only a low intensity of light is required.

The mechanism controlling the flowering of the plant is not, however, so much affected by the increase in the length of the day as by the shortening of the night, and instead of providing a relatively long period of artificial lighting from dusk onwards, the same effect can be obtained by shortening the night. This is achieved very effectively by providing a period of about two hours of artificial lighting in the middle of the night—a system now widely adopted in commercial horticulture. In effect, the plant is receiving two short nights in place of one long one. Conversely, the chrysanthemum can be made to flower during that part of the year when the night is normally short and the day long by means of opaque screens that are placed over the plants to give an artificial shortening of the day. Such work is fascinating, indeed, but there is still much work, to be done in this comparatively complex field of investigation, and the closest collaboration between the lighting engineer and the horticultural experimental stations is needed even more than in the past.

For the future, electronic equipment in various forms will undoubtedly be in evidence on farms, and, in fact, electronic devices are already in use for controlling milking machine pulsators and " mist " propagation compartments. A recent demonstration staged by Reading University and the Electrical Research Association has also given a pointer towards new developments in the automatic control and programming of tractors. The possibilities of such a control system for field work are immense, but it may well be that research into such matters will take five years or more. Automatic tractors able to carry out a wide variety of field work are not likely to be in general use for a further five or ten years. During that time, however, many other interesting developments will have taken place, particularly in the direction of intensification of animal husbandry, and in all this work electrical equipment will play a very prominent part.

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DISCUSSION

The discussion was opened by MR. J. T. TAYLOR, agricultural development engineer, The British Thomson-Houston Co., Ltd. He welcomed the fact that the Paper had not merely given a list of electrical applications, but went further to give the reasons underlying such applications and some account of the results obtained from them.

Mr. Taylor made the following comments on specific points in the Paper. Where it had been stated that the frame size for a 10-h.p. motor with Class " A " insulation would now accommodate a 15-h.p. motor with Class

" E " insulation, it should be borne in mind that this applied only to 3-phase units, not to single-phase owing to torque limitations. The list of different motor-enclosure types he declared unnecessary, as he considered that only the totally-enclosed fan-cooled motor was to be recommended for farm use, where dirt was encountered in every situation.

Regarding the selection of motors being dictated primarily by starting current, in his experience, choice was based upon price, starting current and also upon starting torque. The torque was an unavoidable factor, and to obtain it a certain starting current was necessary, so that torque and current were always closely associated.

The farm machinery manufacturer designed a piece of equipment to do a certain job and then called upon the electrical manufacturer for a motor to operate it. A motor could always be specified, but the problem arose, could it be connected to the supply ? In Mr. Taylor's view, the electrical manufacturers must get together with the supply authorities on this matter. It would be of great advantage if the authorities could give a definite ruling for motors of up to 5 h.p., especially on single-phase supplies, which were most commonly being installed on farms now.

Motor manufacturers had a large part to play in keeping costs down. Basic dimensions were now the same for all makes under B.S. specifications, which was a great help. Frequently, however, machinery makers produced designs which omitted the motor till the last minute and, as a consequence, specially modified motors were required to fit them. If this could be avoided, better service and lower prices would result.

In Table 3 Mr. Taylor was surprised not to see the repulsion-induction type of motor listed. Although expensive, this pattern was of wide application where high torques were involved, and their starting conditions of 200% of full load torque with 400% of full load current were unbeatable, and impossible with a squirrel-cage capacitor type except by shortening its life drastically.

MR. T. HERD, London sales manager, Brook Motors, Ltd., suggested that the high torque requirements for starting fully charged meal-mixers could be reduced by having the auger running free initially. This could be achieved by movable flaps holding the meal clear of the auger until it had gained speed.

In single-phase supplies, said Mr. Herd, the biggest bugbear was voltage drop. It was aggravated by many farms performing the same jobs at the same times. If work could be staggered, using time switches for some tasks, off-peak periods could be utilised when the voltage was high and stable. Favourable off-peak tariffs should be offered by all the supply authorities to encourage farmers to do this.

New insulating materials admittedly allowed more compact motor design, but efficiencies and power factors remained the same, so the heat to be dissipated from, say, a 5-h.p. 1,500-r.p.m. motor was as much as before. Ventilation was, therefore, of vital importance. In the slide shown of a hammermill installation the motor ventilation inlet was correctly positioned away from the adjacent wall, but how often was this the case in practice ? Too frequently scant attention was paid to such matters.

Mr. Herd wondered why more use was not made of pipe-ventilated motors. A pipe was required only on the inlet side, and the dust-free ventilation was very useful on farms. On the standard totally-enclosed type the external ribbing could and did get clogged with refuse. Drip-proof designs were nearly all base-ventilated, and should therefore be sited off the ground if the danger of blockage were to be avoided.

With single-phase supplies now to the fore, many types of starting equipment were possible, and Mr. Herd agreed that standard supply regulations covering the whole country would be a great advantage. He thought that consideration should be given to accelerating torques as well as to starting torques. With single-phase, at the changeover from the starting position to the running position, a break of supply occurred which could be dangerous if it coincided with a voltage drop, remembering that accelerating torque varies approximately as the square of the applied voltage.

DR. R. C. G. WILLIAMS, chief technical adviser, Philips Electrical, Ltd., said electrical engineering could be divided into two distinct branches, the heavy supply or power side and the light electronics side. Mr. Finn-Kelcey had shown himself very conscious of this division.

Dr. Williams was primarily concerned with the electronics side. Electronics would in future affect our lives to a much greater extent. The electronic engineer was continually faced with a mass of new inventions. On the " light " side, the Institution of Electrical Engineers was presented with about 300 Papers a year, compared with 30 on the " heavy " side. Many were on subjects unknown 10 years ago, and the electronic engineer had to adapt himself to the idea of developments being quickly outdated, with a great deal of experimenting and rapid obsolescence. Specialised branches of the science were beginning to be recognised and used—*e.g.*, medical electronics, and there seemed no reason why horticultural electronics might not be a future possibility.

Referring to the Paper, Dr. Williams noted the criticism that ordinary light meters were of no use for measuring the light available to a plant. He agreed that an absolute unit of power should be used—*e.g.*, milliwatts per square metre, but pointed out that the waveband should be specified over which it was measured. He asked if any more information had been obtained on the use of high-powered neon lighting in plant growth ; he believed developments had gone ahead in the U.S.A. in this connection.

With regard to Table 4, he considered the predominant colour of tungsten lamps to be not " white," but red-orange. Sodium lighting was noted as being of " high capital cost," and while this was true as far as it went, all gas discharge illumination was more efficient and economical than other methods if all things were taken into account. For lighting large areas such as farmyards, he would strongly recommend sodium lamps. Marked developments were also under way with fluorescent lighting, and he believed this would soon be as efficient as the gas discharge method..

Applications of electricity to horticulture and agriculture not given in the Paper but worth mentioning were: (1) Very short wave ultra-violet light to kill viruses, bacteria and moulds. It could check virus pneumonia in pigs, fowl paralysis and other diseases, and control the working and storage of cheese. (2) Longer wave ultra-violet for fruit and egg grading and packing. (3) Red fluorescent lighting to reduce feather-plucking and cannibalism in poultry. (4) Infra-red heating for chicken, pigs, calves, and also for people working in a large space which could not be heated throughout. (5) Tubular and cable heating for soil warming, etc. This lent itself well to automatic control. (6) Air humidity control in glasshouses, stores, etc. This might possibly be extended to the control of soil moisture and the automatic supply of irrigation water. (7) Sound effects. Music played to cows during milking had been shown to have beneficial tranquilising properties.

MR. E. C. CLAYDON assured the audience that all the Electricity Boards offered favourable off-peak tariffs. He said the trouble was that electrical manufacturers had shown no interest in the agricultural market until very recently ; it was now high time they took action regarding the starting current problem, which was of serious concern, especially near built-up areas.

MR. G. MAY contended that nowadays many motors supplied with agricultural equipment were grossly under-powered for the job, and it was now the practice on his farm to test each unit upon installation and to refuse payment unless the motor size was adequate. Totally-enclosed motors should be the rule, as farmers never cleaned them and other types collected lots of rubbish. Direct drive was a great asset ; belt drives often suffered damage from rats. Automatic switchgear was too expensive and should be simplified. He did not see why cable supply to electrically-driven farm tractors should not be a possibility ; it had been done in Russia and the electric tractor would solve many maintenance problems.

Doubts about the value of totally-enclosed motors were expressed by MR. H. G. T. WILD. In his experience over many years he had found few troubles with protected types and they had involved little expense. On the other hand, several instances of failure of totally-enclosed motors had come to his notice.

MR. T. P. GREGORY thought belt drives were best in case of electrical breakdown of an essential unit—*e.g.*, a milking machine. An alternative engine was kept in readiness on his farm, and it was an easy matter to change over the belt to that engine if necessary.

Referring to the tractor-mounted generator driving a mower, shown in some of the slides, DR. P. PAYNE wondered if any data had been gained on p.t.-o. power requirements, which had been a largely unknown factor up to the present.

Replying to some of the horticultural questions on behalf of Mr. Finn-Kelcey, MR. A. E. CANHAM said high-powered neon lamps had interested horticulturists for some years. At Shinfield (E.R.A. Field Station) they had experimented with lamps of up to 400 watts, and found plant response to be satisfactory, but the cost of the lamps and auxiliary gear was too high. If alternative cheaper control equipment had been developed in America they had not yet heard of them.

Mr. Canham agreed that tungsten lamps produced a fair proportion of red light. Sodium lamps had proved costly when used for irradiation ; 140-watt units were the largest available, and although a double unit had been developed this still involved two sets of control gear and added expense. For flood-lighting large areas they were certainly efficient. The advances forecast in fluorescent tube design were awaited with interest.

MR. FINN-KELCEY backed the proposal for standardised supply conditions for motors of up to 5 h.p. He said the electronically-controlled tractor should be viewed in the light of probable progress during the next 5, 10 or 15 years and not relative to farming as we know it to-day ; for example, mouldboard ploughing might not be practicable with the system, but rotary cultivation might be the rule in future.

To Mr. Gregory's proposal for alternative drive, he suggested direct drive could be retained, with a double-shaft extension motor fitted with a pulley to accommodate drive from an emergency source.

In reply to Dr. Payne's query about the tractor-mounted generator, he said the old rule of thumb estimate of ½ h.p. per foot cut of mower had been proved almost exactly correct—*i.e.*, 2½ h.p. for the 5-ft. cutterbar, the regrettable truth being that 2 h.p. was employed to overcome blade inertia and ½ h.p. for the actual mowing.

RECENT BOOKS

" **Machines on the Farm,**" by H. J. Hine, B.Sc., M.I.B.A.E. (Odhams Press, Ltd., 24, Henrietta Street, London, W.C. 2. Price 25s.),

emphasises the importance of the efficient operation of agricultural machinery of all kinds. The author, whose contributions to the literature of farm machinery are well known, has not merely described those implements and machines which are required throughout the course of a farming year. He has indicated in readily understandable language operational and maintenance methods by which a high standard of machinery reliability is achieved so that valuable time is not lost because of breakdowns and expenditure on repairs and spares is kept to the minimum. As the author points out, success in farming depends largely on getting the greatest output with the smallest expenditure of money and time, consistent with maintaining land in good heart and, of course, machinery is one of the most important factors in helping towards that end. All who are concerned with purchasing, operating and maintaining farm machinery will find this book a helpful one. Students, too, will find it useful for increasing their knowledge of machinery maintenance and the economics of machinery utilisation. The book is well illustrated and, in addition to those chapters covering the full range of machinery for arable farming and stock-feed preparation, includes valuable material on such important subjects as power units and farm transport.

" **Farm Work Study,**" by Nigel Harvey, M.A. (Farmer and Stockbreeder Publications, Ltd., Dorset House, Stamford Street, London, S.E. 1. Price 8s. 6d., postage 8d.),

explains succinctly that there is nothing mysterious or difficult about work study. It is well recognised that work study is beneficial to industrial productivity, and it is becoming more and more evident that its application to agriculture can be equally beneficial. Mr. Harvey presents a complete guide to work study on " do it yourself " lines. His book contains many pages of explanatory plans and diagrams as well as seven case studies which show, step by step, how work study has been applied to save labour on general and poultry farms and in market gardening. This is a book which will be of particular interest to those who attended the Work Study Conference last year, in the organisation of which the Institution participated.

" **Farm Organization and Management,**" by Gordon Hayes (Crosby, Lockwood and Son, Ltd., 26, Old Brompton Road, London, S.W. 7. Price 25s.),

is intended primarily for students, graduates and farmers. It does not purport to be a textbook on agricultural economics, but it does set out a great deal of useful information on the organisational problems with which farmers must deal if they are to achieve a measure of success. At first glance, the book may not seem to have much appeal to agricultural engineers. But agricultural engineering students and those already qualified who wish to keep themselves informed on various aspects of farm management will find this book useful for the purpose.

" **Farm Mechanization Management,**" by C. Culpin (Crosby Lockwood & Son, Ltd., 26, Old Brompton Road, London, S.W. 7. Price 21s.),

deals in a very practical way with the economic aspects of applying power and machinery to British agriculture Mr. Culpin's work is well known, especially to members. of the Institution. In this, his latest book, he has not concentrated so much upon detailed descriptions of up-to-date farm machines, but rather upon their economic suitability for the many work problems arising during the course of a farming year. The cost and profitability of mechanization are matters of prime importance to a farmer ; they are also matters on which designers and manufacturers of agricultural machinery need to be well informed. One of the many useful chapters of the book is that entitled " Work Study and Mechanization." The author does not hesitate to point out that there are differences of opinion as to how work study can best be applied, and his exposition of the " method study " approach is to be commended. The book is well illustrated. Moreover, in an appendix, there has been brought together statistical material of a kind which is often needed but is often difficult to find.

CULTIVATION OF SUGAR CANE AND RICE

by A. C. HOWARD, M.I.B.A.E.

A Paper read at an Open Meeting on Tuesday, 10th March, 1959

SUMMARY

Accounts are given of the cultivation of sugar cane and rice. Sugar cane is grown in many countries on a great variety of soils, under differing climatic conditions, at elevations from sea level to 4,000 ft. and by peasant farmers as well as on large estates. This leads to variations in the methods of cultivation to suit the conditions of the individual areas and, hence, there is no method of cultivation which can be described as typical. An attempt has been made to indicate some of the problems in the production areas and the mechanisation of the cultivation on large estates.

The largest areas of rice are in Asia on small holdings which do not lend themselves readily to mechanisation. However, some mechanisation has taken place and is described. In the areas where rice is grown outside Asia, the holdings are larger and mechanisation of the cultivation and harvesting operations is advanced. The use of some implements in these larger areas is described.

CULTIVATION OF RICE

RICE is one of the most important food crops of the world and forms the staple food of a large proportion of the population of Asia —in which Continent it is mainly grown.

In the earliest days rice growing was probably confined to deltaic areas, since it is in such areas that the large quantity of water required during its growth is most easily available. Later the cultivation was extended to the alluvial plains of rivers after irrigation works had been constructed, and it is now also grown under controlled irrigation from hill streams in India up to some 6,000 ft. elevation. Rice cultivation has more recently been extended to the warmer parts of both North and South America, to the West Indies, to Southern Europe and to Australia.

In the production of crops other than rice one of the main objects of the cultivation operations and the rotation of crops is the creation and maintenance of soil structure. Under the traditional flooded conditions the preparation of the seed bed for rice involves the complete destruction of soil structure, a result much more easily produced than the creation of structure. The cultivation of rice represents, therefore, the most primitive form of agriculture and is suitable for communities with the most primitive implements.

With the exception of Siam, Japan and Malaya, the production of rice in Asia has not been mechanised to any great extent. The method of cultivation of rice in India, where some 60 million acres are grown, may be taken as typical of production in Asia.

Cultivation

The fields are flooded with water and then ploughed with the native plough drawn by buffaloes. The ploughing and the trampling of the buffaloes puddles the soil. Frequently manuring is practised, the green manure being supplied by the leguminous plant Jantar, also known in India as Dhaincha. The green manure is trampled into the puddled soil by the buffaloes. After the soil has been thoroughly puddled, wooden sleepers are drawn over the soil to level it. The field is then divided into small compartments by low mud walls. This is necessary to ensure the even distribution of the water over the field.

Sowing

The seed is either broadcast or sown in nursery beds to provide plants for transplanting. As a rule broadcast yields are lower than those obtained by transplanting. This is probably due to the better spacing of the plants obtained by transplanting.

When the seed is to be broadcast it is usually soaked for 24 hours and then heaped and covered with sacks for a few days. This allows the initial germination to take place before broadcasting. When the crop is to be transplanted the seed is sown in a nursery, and when the plants are about 8 ins. high they are ready for transplanting. The plants are transplanted by hand, some 9 ins. apart, and two to four plants per hole. When the crop has been sown or transplanted the land is then kept flooded until the flowers have been produced. The water is then reduced and finally, in order to hasten ripening, the field is dried off. The length of time from sowing to harvest depends on the variety and may be from four to seven months.

Harvesting

The crop is cut by hand and tied in sheaves which are allowed to dry in the sun. It is usually thrashed by beating the sheaves against a low wall, trampled by the oxen being led round and round, or other primitive forms of threshing.

Mechanisation

In Siam and Malaya some mechanisation of the cultivation operations has taken place. Instead of the buffaloes and native plough, the hand-controlled Rotavator, and to a small extent the tractor-mounted Rotavator have been introduced. The soil is much more efficiently puddled by the Rotavator and yields, following rotavation, are much higher than those following the cultivation with the buffalo and plough.

For the small area cultivation we have developed a special model of our 9-h.p. hand-controlled Rotavator. It is equipped with large spade-lugged wheels and the engine and all gearing waterproofed so that it can work under the conditions for which the buffalo is now used. On all our Rotavators for working in rice land we fit a special form of blade to enable the rotor to cut through or throw off the slimy mass of vegetation and mud without clogging.

In Japan a hand-controlled rotary cultivator of local manufacture has also been introduced for rice cultivation.

Cultivation of Rice Outside Asia

In California and Australia the mechanisation of rice cultivation has gone much further than Asia and, indeed, most other countries. Both ploughs and tractor-drawn Rotavators have been used for the preparation of the seed bed. The fields in these areas are large and they are not divided into small sections to obtain the even distribution of the water. Instead an implement called a land-plane is used to obtain dead level surfaces to secure an even depth of water over the large fields.

The seed is generally drilled as with any other cereal crop. After sowing the crop is generally treated much the same as in India until it is ready for harvesting. As the rainfall during this period is nil the water can be controlled with great accuracy.

In preparation for harvesting the land is dried off. The crop is harvested by combine harvester. The main difference between the rice combine harvester and that used for other cereals is that the rice harvester is mounted on tracks, or giant pneumatic wheels, on account of the unstable condition of the soil due to the water which it still holds at the time of harvest.

In between these two extremes—*viz.*, where the control of water is very difficult owing to the rainfall and where perfect control can be obtained, such as in Australia and California, there are numerous areas new to rice where the cultivation has been scientifically designed and where land grading and water control has enabled mechanisation to be more or less successful, even though the rainfall is high. Notable in this class are Cuba and British Guiana.

In these two areas, as well as many others, the science of growing rice has developed a long way in the last ten years. In British Guiana, for instance, as soon as the rice crop is harvested the rice straw is returned to the soil promptly, chiefly by tractors and Rotavators, and every opportunity is taken of what dry weather there is to prepare for the new crop without having to work in water. The rice crop is very largely put in by seed drill. Under some conditions it has to be broadcast and the crop is entirely taken off by combines, but of course, as the natural rainfall is so high, the ideal conditions prevailing in California and the irrigation areas of Australia do not apply.

With regard to the small areas : On my recent visit to Trinidad I was very surprised to find the mechanisation development that has taken place since we first introduced our hand-controlled machines into the rice field some ten years ago. In fact, what were more or less the peasant rice growers in Trinidad have now developed into quite prosperous mixed farmers and truck farmers with rice as a side line.

With the help and guidance of a benevolent agricultural department they seem to have very largely got over the troubles of the tiny plots which previously existed when the mule or oxen were the only forms of power.

Quite a number of hand-controlled Rotavators were sold a few years ago for working the rice plots, but the greater part of the heavy work is now done by contractors equipped with tractors and rotary hoes. Of course the farmers still have their hand-controlled machines and other implements for the light work, but as soon as the rice is harvested the farmer has his ground rotavated and in a few weeks it is ready for the next crop. As many as three crops a year are being taken from the same land by the more progressive people. Where rice only is grown the land is drained off promptly, the straw rotavated in, and the land used for grazing for the rest of the year.

Under the wide variety of conditions under which rice is grown there are wide variations in yield and in the manpower required for cultivation with the different systems. For instance, under the traditional wet paddy system the average yield is about 30 bushels per acre and one man per acre is employed to carry out the work. Under the highly-mechanised systems, as practised in California and Australia, the average yield is about 100 bushels per acre and the manpower required is one man per 100 acres.

Mechanisation Required for Rice Growing

The present equipment available for the large areas of rice where the water control is satisfactory seems to be adequate, but for the intermediate and small grower it would appear that there are many missing links.

The rice experimental station in Trinidad is carrying out a lot of experimental work to discover means of helping the small rice farmer.

I spent a few hours with Mr. Rasher who is in charge of the mechanical section of this work. He showed me several very ingenious machines and implements on which he is working. These are mostly in the experimental stage, but he has one machine which he states has now been well tested and is ready to be put into production.

This is a small threshing machine which can be attached to a Rotavator or other hand-controlled machine to provide the engine power for the threshing drum and transport it from place to place.

I understand the design of this machine is available to a suitable manufacturer who would undertake to supply the market.

THE MECHANISATION OF SUGAR CANE CULTIVATION

Introduction

Sugar cane is usually regarded as a tropical crop though it is grown outside the tropics in a number of areas such as the United States, Hawaiin Islands, Natal, Australia and Egypt.

The principal sugar-cane countries are the West Indies, Cuba, Brazil, Java, India, British Guiana, Australia, South Africa and the Phillipines.

With this wide distribution of growing areas great variations are experienced in the climatic conditions, the soil types and the altitude at which sugar cane is grown. It follows that the cultivation operations employed to produce the crop are also subject to great variation. An attempt will be made to discuss the reasons for some of the cultivation operations and to indicate the mechanisation that has occurred in connection with them.

In many areas the crop is grown by peasant farmers. Owing to the small size of the holdings of these peasant farmers and to their lack of capital, cultivation under peasant farming conditions has not, and is unlikely to be, mechanised to any great extent. Mechanisation of cultivation has taken place on the large estates in the United States and Dependencies, the West Indies, British Guiana, Australia and South Africa. These mechanised areas probably amount to some 6,000,000 acres and produce about one half of the world output of sugar from cane.

Sugar Cane Climates

When the crop is grown on rainfall it seems to be generally accepted that 60 ins. of effective rainfall are required to mature the crop. An exception of this is Natal where the effective rainfall is about 41 ins. Even with an effective rainfall of 60 ins., irrigation during dry periods results in increased yields of cane.

In Egypt the effective rainfall is nil. The crop is dependent entirely upon irrigation for its water supply. In the Punjab the effective rainfall is about 15 ins., so that here again the crop is largely dependent upon irrigation.

Sugar cane grows best in a hot climate. It is particularly susceptible to damage by frost. In the Punjab frost may occur in January, so the cane is usually harvested by the end of December to avoid damage. As a result the growing period in the Punjab is only of ten months duration compared with ten to fourteen months in most other areas. The short growing period in the Punjab results in very low yields of cane.

Owing mainly to the effect of temperature, cane is not grown above an altitude of 4,000 ft. In Uganda it is grown at this height, and as a result of the comparatively low temperatures the period between planting and harvesting is about eighteen months.

In British Guiana sugar cane is grown below sea level. This introduces problems of drainage and necessitates an irrigation system to provide water for the control of the salt content of the soil.

Soil Types

Sugar cane is grown on a great variety of soils, each soil type presenting its own cultivation problems. In the tropics it is grown extensively on lateritic soils. It is also grown on sandy loams, clay loams and heavy clays. In Florida the sugar cane area is on reclaimed peat. With such a variety of soils the cultivation methods for producing a seed bed and to control moisture conditions in the soil are also very variable.

Drainage

On the lighter soils the natural drainage is usually adequate. As the clay content of the soil increases so drainage becomes more and more important in some countries. On suitable soils with a good structure tile drains are frequently used. It is essential that the minimum depths of the tile drains be well below the maximum depth of cultivation, which may be as much as 24 ins. Trench diggers with a tile laying attachment could be used for constructing this type of drainage system. This would greatly reduce the cost and should enable this system to be greatly extended. Mole and tile drains have been used successfully in Fiji and Florida.

On suitable soils mole drains constructed with the usual tool have been successfully used. Mole drains are not suitable for soils in which soluble salts accumulate in the soil at the depth of the drain. The salts cause flocculation of the clay which reduces cohesion and the drain collapses.

Drainage is one of the most important cultivation operations on the heavy soils. If water stands on this type of land after rain tilth is rapidly lost. The sugar cane crop itself is seriously damaged if the land is waterlogged for more than a few days. On the heavy soils drainage is usually by open trenches which lead to main drainage channels. The lands between the trenches are the planting beds. The intervals between the trenches consequently determine the size of the planting beds and the spacing between the rows of cane. As examples, when the intervals between the drains is 22 ft. the spacing between the cane rows is 5 ft. ; when the intervals between the drains is 24 ft. then the row spacing is 5 ft. 6 ins. The spacing between the cane rows in turn determines the width of the tractor and the cultivation implements that can be used once the cane has been planted. The cane rows are generally planted parallel to the drains so that the mechanised cultivation operations do not damage the drains.

The field drains are excavated with specially constructed ploughs and graders and, as they are constructed in heavy soils, necessitates high-powered crawler tractors. The trench system of drainage is cheaper to construct than the tile system though, as it is more easily damaged by cultivation operations, the maintenance costs are higher. An objection to the trench system of drains is that the area of land under crop is reduced.

Cultivation Operations

Before the drains on heavy land are constructed the land is ploughed and subsoiled. The usual depth of ploughing is about 12 ins. and is carried out either by mouldboard or disc plough and in some cases by heavy Rotavators.

Subsoiling is done with tines mounted on a heavy frame. The depth of subsoiling is usually between 21 and 22 ins. The object of the operation is to improve drainage and aeration.

Planting

The cane can be planted by hand or mechanically. In either case the cane is cut into sections each having three nodes. The method of planting these setts by hand varies. In some areas two setts are planted at each side of irrigation furrows in holes so that the setts are at an angle of 30 degrees to the vertical. In other areas a furrow is made 4 ins. to 8 ins. deep and the setts laid at the bottom of the furrow. The setts are covered with soil to a depth of 2 ins.

The mechanical planter is very simple. It consists of a wagon on to which the setts are loaded. The wagon is fitted with a shoot and the setts are fed by hand into the shoot which delivers them to the furrow. Planting mechanically has an advantage over hand planting in that the land is not compacted during the process.

Weeding

With the high temperatures and high rainfall of sugar cane areas weeds grow rapidly and it is essential to control them if maximum yield is to be obtained and if difficulties in harvesting are to be avoided. In latter years weed control by chemical weedicide spray has become very popular after planting. On heavy soils it is difficult to get effective control by this method as the clods tend to be large and the weed seeds which they contain are not affected by the spray. An improvement of the effect of the pre-emergent spraying can be obtained by rotavating the ground prior to the application of the spray. The Rotavator reduces the size of the clods and consequently the spray has greater penetration.

Implements cannot be used to control the weed growth after planting until the cane has produced its secondary shoots to form the stool. When the stools have been produced rotary cultivators, either hand controlled or tractor mounted, can be used to keep the land clean. In addition to controlling the weed growth the rotary cultivation brings the fine soil up against the plants, thus stimulating their growth.

Harvesting

Harvesting is generally carried out by hand, though some mechanical harvesters are now coming into use. When done by hand the cane is cut close to the ground and the trash stripped off it. In many countries the trash is usually burnt off before starting the operation.

Ratoon Crops

After harvesting the stools continue to grow and produce further crops of cane. Each crop after the first is known as a ratoon, first, second, third, etc. The number of ratoon crops taken varies from area to area.

Disposal of Trash

After the cane has been harvested it is impossible to work the soil until the trash has been dealt with. Formerly the trash was piled into alternate rows so that the cleared rows could be worked.

A specially designed Rotavator has now been developed for the purpose of cutting up the trash and incorporating it with the soil. The Rotavator has a roller attached to the frame. The roller holds the trash firmly on the ground whilst the blades of the Rotavator cut up the trash and intimately mix it with the soil where it decomposes and becomes incorporated in the soil in a very short time.

By using the Rotavator it is possible to maintain the humus content of the soil throughout the period of the ratoon crops. The same Rotavator is used for incorporating green covercrops into the ground and for inter-row cultivations.

DISCUSSION

MR. W. BOA of the N.I.A.E. opened the discussion. He said one common method of disposing of cane trash was by burning off—*i.e.*, firing the dead leaves and undergrowth with the crop standing, leaving the cane to be harvested afterwards. With very heavy crops, of over 100 tons per acre, burning was essential.

This technique had two severe disadvantages, however. First, the cane had to be harvested fairly soon after burning ; after 72 hours, deterioration began to set in. Secondly, the ground trash blanket was lost.

Trash blanketing could be knee-deep, and had the following beneficial effects : (1) It stopped the rain beating the soil surface, so lessening erosion risks ; (2) the soil was effectively insulated ; (3) moisture was retained in the soil and (4) weed growth was prevented. Fertilisers from the bag were possibly made more readily available. The second and subsequent ratoon crops were consequently higher if the trash was left than if it was burnt off, so the right method appeared to be to keep the trash on the surface.

Few experiments had ever been carried out on the subject, but Pearson in 1955 had conducted trials in which one plot was burnt off and green manured, a second had its trash ploughed in followed by green manuring, and a third had its trash raked off and was not manured. The subsequent ratoon crop was the same in all cases, but a fourth plot which had been rotary cultivated yielded 6 tons per acre less. This substantial loss might be accounted for in a number of ways and the experiment was far from conclusive, but it pointed away from the principle of incorporating the trash intimately with the soil.

Sugar-cane agriculturalists were far from satisfied with present methods, concluded Mr. Boa. They were constantly seeking new methods of culture and agricultural engineers would do well to keep up with them.

MR. R. M. CHAMBERS of Massey-Ferguson, Ltd., made some comments on rice mechanisation. He said Mr. Howard's Paper and film appeared to be largely confined to conditions in certain areas, notably Siam and the U.S.A. But circumstances varied vastly in other parts of the world. In India, for example, oxen were largely used for cultivations, not buffaloes. This at least precluded the hazard of deep holes under water caused by buffaloes, which wallow to keep cool ; such holes could be most embarrassing to tractor demonstrators when the help of a large crowd of onlookers had to be enlisted to hoist their machine out !

With rotary cultivation in normal dry conditions, tractor designers relied largely upon the grip of the blades in the soil to assist in propelling the tractor forward. No forward thrust of this kind could be obtained in wet rice-fields, and in India it was found that the rotary cultivator tended to keep digging holes.

One important point Mr. Howard had failed to mention was how the farmer was going to pay for mechanical equipment. Farm machines must either : (1) Help pay for exports, (2) reduce imports, or (3) improve the standard of living. At least two of the above conditions must apply, otherwise failure would result. It was useless to expect merely to maintain the *status quo*.

Now, it had been calculated that to pay for an £800 machine a farmer in the U.S.A. must sell 14·3 tons of rice ; in Italy 20·1 tons ; in Brazil 51 tons and in India possibly 60 to 70 tons. Very little money was made from growing rice in small areas. Conditions were exceptional in California where aerial seeding, fertilising and weed spraying were carried out, and the harvesting of 100-bushel crops was done by large combines.

Regarding sugar cane, Mr. Chambers asked for Mr. Howard's opinion on wider row widths, to facilitate mechanical cultivation. In South Africa he believed 6–6½ ft. had been tried, giving plenty of room between the rows even with the crop well grown. Had this reduced yields significantly ? He also asked what chance there was of applying machinery in the method where the stools straddled the irrigation channels. He, too, was of the opinion that smothering weeds by trash was better than control by cultivation or chemicals.

Replying, MR. HOWARD admitted that tractors and rotary cultivators got stuck in wet paddy fields, but long flotation skids were available for all Rotary Hoes' machines which should be used (but frequently were not) to control the cultivation depth. Normally 6 ins. was the maximum desirable cultivation depth.

Regarding payment for machines, Mr. Howard reiterated that some communities of small farmers, notably in Trinidad and Malaya, had begun with hand-controlled rotary cultivators and were now prosperous farmers able to pay for having their heavy work done on contract by tractors. One tractor and cultivator could do more and better work than 12 men with oxen. He agreed, however, that mechanisation was still far off in many areas where the population was poor and had no occupation other than farming.

On the sugar-cane question, rows were commonly 5 ft. 4 ins. and 6 ft. apart, and the tendency was for them to get narrower, said Mr. Howard. With 5-ft. rows, which were increasing in popularity, it was impossible to get a stable machine for sloping ground as the maximum width of tractor and implement was only 3 ft. ; one solution was to have a fairly high-clearance tractor straddling a row with a 3-ft. cultivator offset to work in the track of one wheel. Where rows were planted along irrigation furrows, a 30-in. cultivator was the widest it had been possible to use.

COL. W. N. BATES said in Northern India cane-planting distances were 3 ft. to 3 ft. 6 ins., and in the Deccan 4 ft. 6 ins. to 5 ft. He believed that in Natal 4 ft. 6 ins. to 5 ft. 6 ins. was the rule. On the economics of mechanisation, he reminded the audience that 90% of India's population lived in 500,000 villages and their average annual income was only £20. There was no possibility of paying for rotary cultivators or contract work, and it would take years to build up an efficient repair and service organisation.

MR. D. R. BOMFORD remarked that if the calorific value of rice were about the same as that of wheat, as he supposed it to be, then 30 bushels per man per acre annually was enough for about two people, and that was near the starvation line. The bullocks presumably needed a certain area for grazing, so might not mechanisation release more land for cultivation ?

DR. MACKENZIE TAYLOR replied that the people lived in a state of semi-starvation and the bullocks had nothing specially grown for them. They lived on straw, coarse grass and whatever refuse they could pick up. In Northern India, on a 25-acre holding, a quarter of the area would be under cultivation in summer and the rest fallow due to lack of water ; in winter a half would be cultivated. It would be far too expensive to grow bullock feed.

MR. FRANCIS COLEMAN said the introduction of very small motor cultivators into parts of Ceylon had saved some cattle fodder. They also helped with cultivations at the end of the dry season when the cattle were starved and therefore weak and ill-fitted for work. This allowed a longer growing period for crops and the use of different varieties to give bigger yields.

A tractor and tined implement would be of immense use in these conditions, said Mr. Coleman, even if it were employed for only a small part of the year, to break up the hard ground before the rains began. In Egypt it had been found that the best technique for rotary cultivation in wet paddy was to follow just behind the water, before the soil had become really soft.

The following elections were effected by the Council in February and March, 1959 :—

MEMBERS

St. John Brown, T.R. .. Northants.
Scott, D. A. .. .. Worcs.

ASSOCIATE MEMBERS

Foster, J. A. .. .. Yorks.
Jones, L. W. .. .. Northumberland
Pepper, P. S. .. .. Northumberland

Overseas

Cooper, S. W. .. .. Kenya

ASSOCIATES

Aspinall, A. .. .. Salop
Evans, D. .. .. .. Carms.
Evans, E. E. .. .. Carms.
Hadley, M. J. .. .. Worcs.
Hoadley, R. L. .. .. Kent
Johnson, W. A. .. .. Salop
Jones, A. .. .. .. Warwicks.
Merriman, K. A... .. Cambs.
Potts, G. N. .. .. Northumberland
Ransley, G. A. .. .. Norfolk
Richards, W. D... .. Carms.
Sands, R. H. .. .. Essex
Schafer, J. D. .. .. Northants.
Slater, W. M. .. .. Cambs.
Taaffe, R. T. .. .. Kent

Overseas

Horner, C.G. .. .. Nigeria
Wolton, A.P. .. .. Nigeria

GRADUATES

Nielsen, V. C. .. .. Devon
Plowman, R. W... .. Yorks.

STUDENTS

Rose, G. .. .. .. Essex
Webb, T... .. .. Somerset

TRANSFERS

FROM ASSOCIATE TO ASSOCIATE MEMBER

Jones, S. W. .. .. Yorks.
Parker, R. A. .. .. Warwicks.

FROM GRADUATE TO ASSOCIATE MEMBER

Fox, J. V... .. .. Warwicks.

PERIODICALS RECEIVED SINCE FEBRUARY, 1959

United Kingdom

A.M.T.D.A. Journal.

Agricultural Machinery Journal (monthly).

British Productivity Council Bulletin (monthly).

Farmer & Stockbreeder.

Farming Facts—Association of Agriculture.

Farm Mechanisation.

Hydraulic Power Transmission.

Outlook on Agriculture (I.C.I.) (quarterly).

Power Farming.

Technology (monthly).

Technical Education (monthly).

The Engineering Centre Newsletter.

United States

Agricultural Engineering Journal of A.S.A.E. (monthly).

Agricultural Situation, U.S. Dept. of Agriculture.

Foreign Agricultural Trade, U.S. Dept. of Agriculture.

Bulletins of Engineering Experiment Station, Alabama.

Journal of the Alabama Academy of Science.

Commonwealth Countries

Journal of Agriculture (South Australia).

Queensland Agricultural Journal.

Other Publications

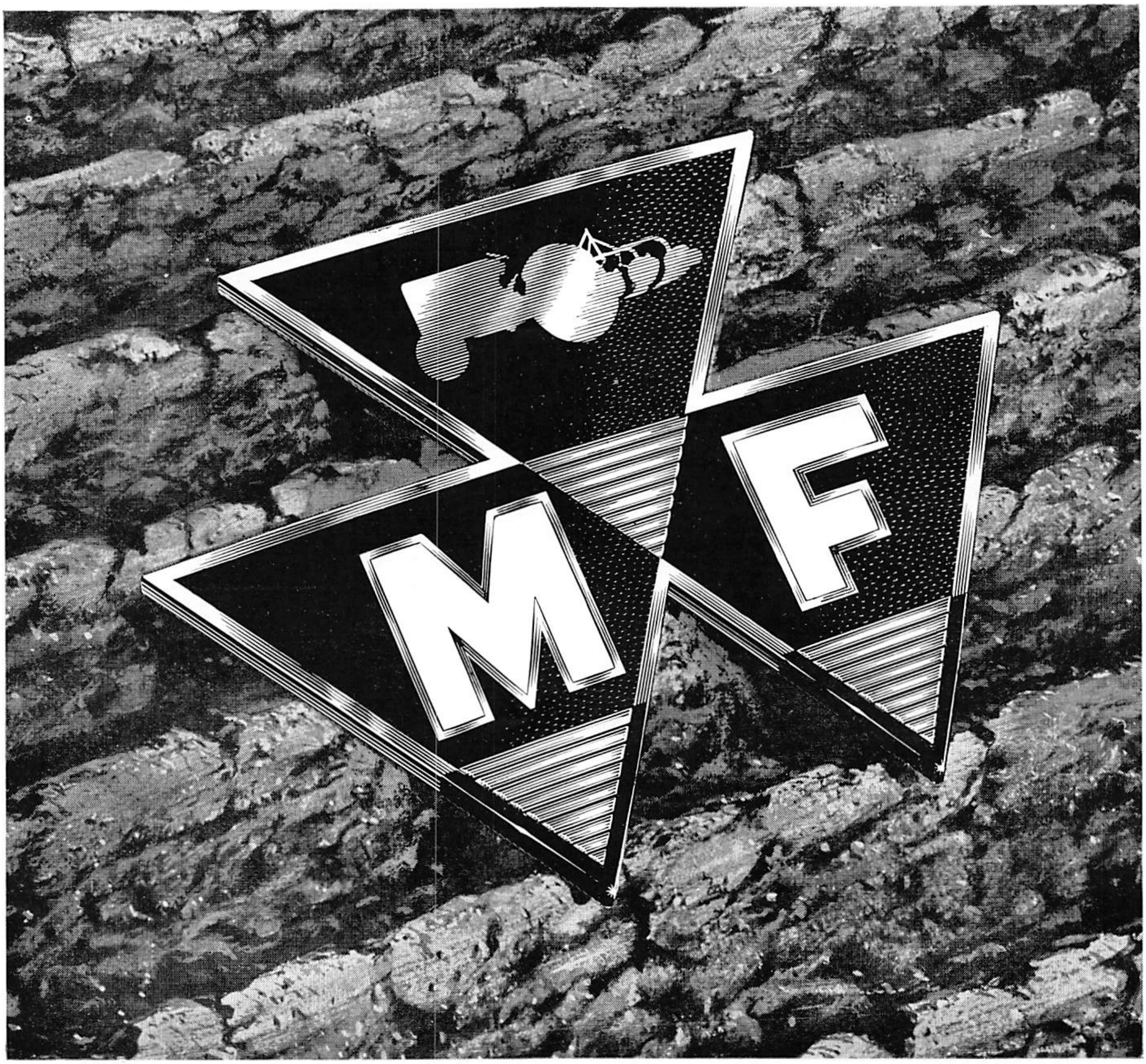
Anais do Institutu Superior de Agronomia (Portugal) (monthly).

Exporter (Germany) (in English).

Mechanisace a Elektrifikace Zemedelstvi (Czechoslovakia).

Memorie ed Atti—Centro di Studi per l'Ingegneria Agraria (Italy).

Progresso Agricolo (Italy).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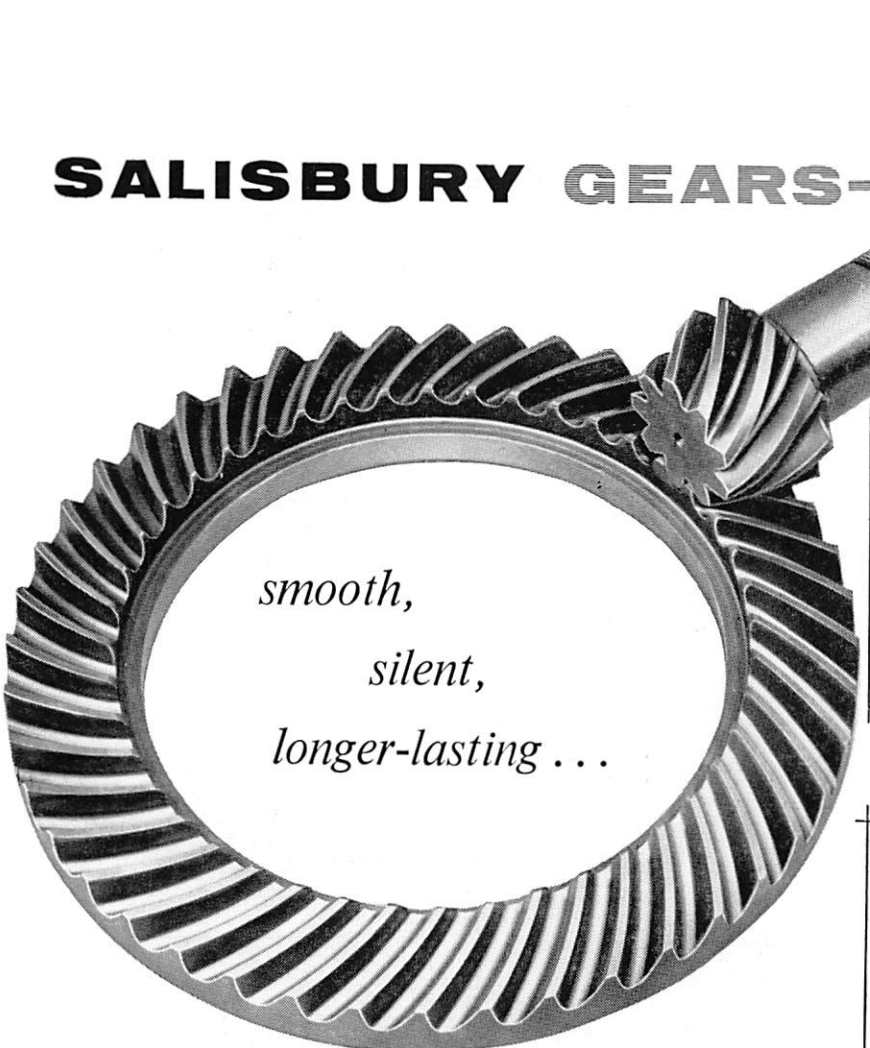

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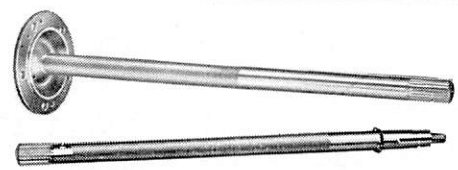

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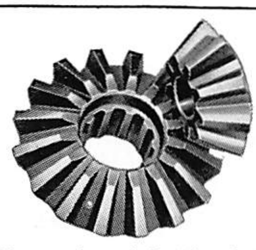

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