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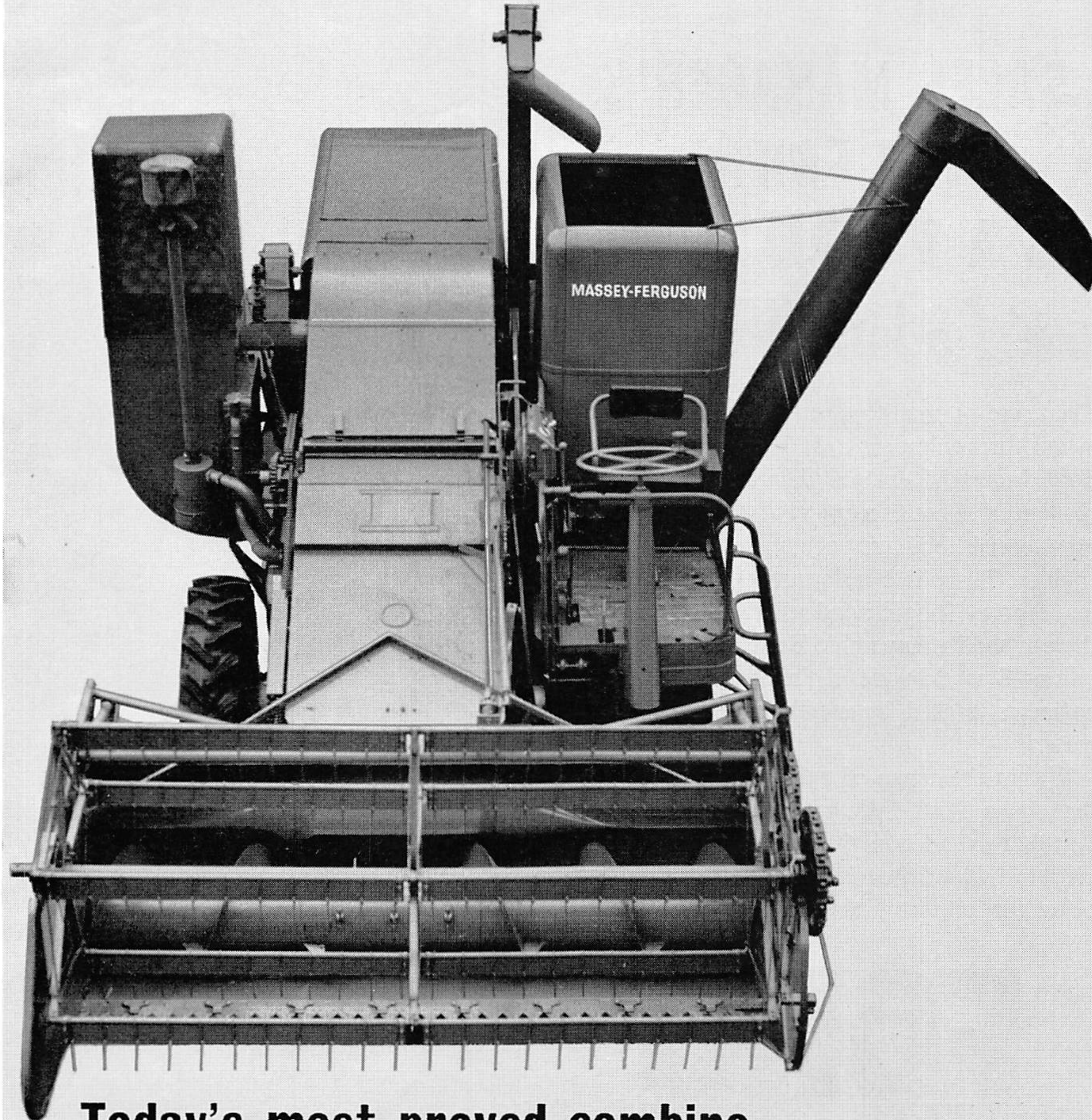

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"THE RIG TESTING OF AGRICULTURAL MACHINERY"

by E. LANG,* A.M.I.Mech.E.

A Paper presented at an Open Meeting on Tuesday, 9th January, at 6.45 p.m. at 6 Queen Square, London, W.1

SUMMARY

THE production of Agricultural Machines by modern quantities and methods makes a high standard of Testing Techniques important both for the assessment of new designs and for quality control. There are many advantages to be gained in carrying out these tests in laboratories rather than in the field, and for this reason rig testing is employed.

The difficulties in recognising and synthesising the relevant features of a service environment, and the establishment of suitably discriminant test criteria, provide a challenge to many engineers.

This paper discusses, practically rather than theoretically, the problems met and a number of typical test rig solutions, and aims to interest those engaged in different branches of agricultural engineering.

What is Rig Testing?

To begin with, the question " What is Rig Testing? " —We shall see that it is synthetic testing in conditions of our own choosing. By synthetic testing it is meant that it tests assemblies by other than real service conditions. In the ideal form of rig test the sub assembly under examination can be artificially set up to operate with:

(1) Regularly repeatable conditions.

(2) Convenient sites for easy and accurate instrumentation; and

(3) Means of adjusting loads over a wide range.

A spectacular example of a large rig test was familiarly known a few years ago to all engineers from their national daily Press, where the Comet I Aircraft Failure Investigation was reported. In this case the aircraft fuselage was subjected to accurately repeated cyclic pressurisations on the ground, where readings could be thoroughly and safely made, and with apparatus that permitted the pressures to be varied at will. Thus this test followed the three main features of rig testing: Repeatable Conditions, Advantageous Siting, Adjustable Loads. In this test the theory proved was that a number of cabin pressurisation cycles induced a fatigue failure and thus cabin explosion. Only a few moments' consideration is necessary to show the advantages of, if not the downright necessity for, employing rig testing in this case.

In contrast, let us consider another test rig, this time a small one, to demonstrate how wide is the definition of " What is Rig Testing? " and also an attractive example of synthesised loadings.

The assembly to be tested was the bearing of a concave soil cutting disc of an agricultural implement. An alternative bearing saving both time and money was proposed and a rig was required to assess its relative performance.

The field loading conditions are best followed on diagram I.

It will be seen that the stationary shaft has two primary forces acting on it, gravity is pulling the implement vertically down, the tractor is pulling the implement horizontally along. The soil, which does not like to be cut, resists both of these forces, while the submerged area of the saucer-shaped concave disc complicates matters by introducing a sideways reaction, and a turning couple in the vertical plane, and a turning couple in the horizontal plane.

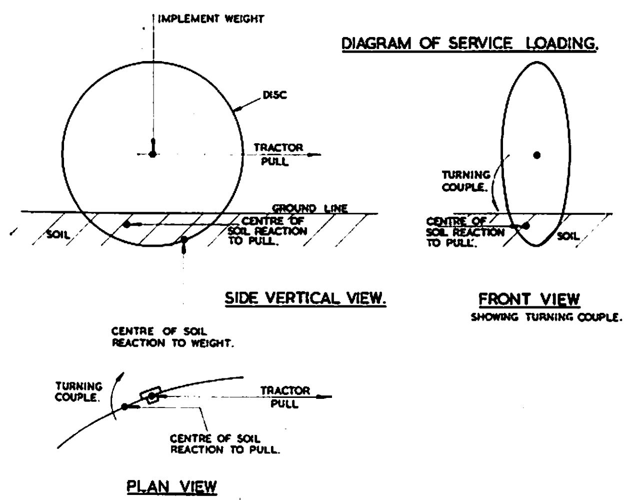

DIAGRAM I

It will readily be seen that the two primary forces, one vertical and one horizontal, can be vectored as one resultant. By the same principle the rig designer simplified out the system into three resultants acting on the bearing, one radial load, one axial load and one turning couple. Estimates of the field loading conditions were obtained from the implement designer, but one further complication remained. For test rig purposes it was convenient to keep the disc stationary and rotate the

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shaft instead, but the loading and wear conditions must be maintained as with "the stationary shaft rotating disc," conditions of service. Diagram II shows designer's appealingly ingenious solution.

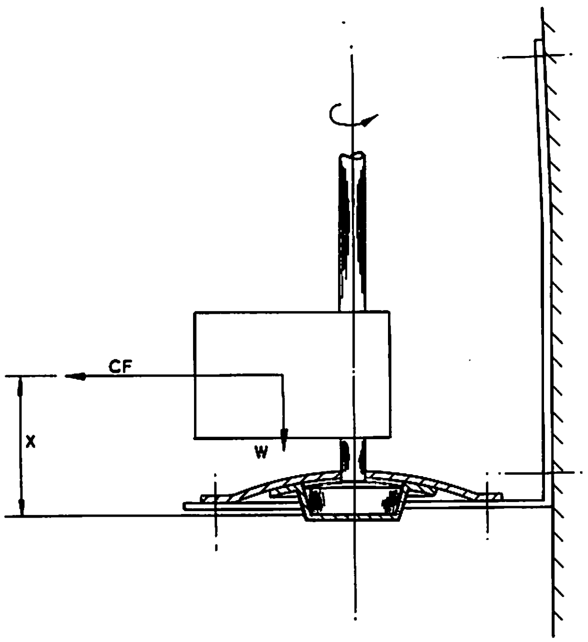


DIAGRAM OF RIG USED FOR SIMULATION OF LOADS SHOWN IN DIAGRAM I.

DIAGRAM II

The outer bearing is stationary, the shaft is vertical and rotated at the predetermined speed by a suitably double jointed drive. One weight only is added to the extended shaft. This weight is firstly equal to the axial load required, it is also sufficiently eccentrically positioned to centrifuge out and suitably load one side of the spindle. The height of the mass is also arranged sufficiently distant from the bearing that the centrifugal force also provides the desired turning couple. As a final refinement the whole rig is hung on the wall, saving valuable floor space. This test rig has already shown the metallurgy of the proposed alternative in its initial form to be unsatisfactory (although this of course was not the result expected). The rig will next be employed in assessing revised alternatives based on the lessons learned.

Very different, this rig, from the Comet I fuselage at Farnborough, but both are encompassed by the term "Rig Test," and it is hoped that the extent of the range, and the common factors described, have suitably answered the first question, "What is Rig Testing?"

Why is Rig Testing Used?

Let us now move on to answer the question, "Why is Rig Testing used?" and we shall see that it is used to give previous answers about the future to both the design engineer and the quality engineer.

We have already begun to see some of the reasons why rig testing is used whilst we were seeing what rig testing is. The Comet I, for instance, showed the advantages of safe ground studies with access to full measuring equipment. The biggest single reason, however, is speed. This reason is so important that if all other reasons were removed it would on its own be sufficient to justify and even enforce the need to employ rig testing. We shall see why this need for speed manifests itself if we consider the general design situation and the general production situation.

The advantage of Preview to the Design Engineer. On any quantity production component of, say, a tractor, or an implement, the basic general position is that the user wants:

(1) Trouble free service,

(2) The lowest practicable cost, and

(3) The latest ideas incorporated as soon as possible.

These three features the designer seeks to give to the user, and his skill can often go a long way towards that end by drawing on his experience, learning and aptitude. It would be a bold designer, however, who would claim he has never been wiser after his design has been in service for a year or two. The designer, therefore, always welcomes any evidence of what the future holds. He wants to know whether his design will show itself to be well balanced as regards length of life, that is, that there are no parts which will fail earlier than the designed life; and, for economy, that there are no extravagantly made parts that will long outlive the design life and cost the user money for no purpose. Rig testing can often provide a quick check on this and it can also give a practical comparative assessment between several alternative modifications under consideration for the same job.

Teething troubles from unforeseeable causes can also beset the designer. These teething troubles when found during early service can be serious, and even at their very least form an understandable annoyance to the customer that tends to rob him of confidence in the designer. Again, to take an example from the national Press, the recent trouble with electric trains will be remembered to have attracted a lot of attention. Teething troubles can often be revealed before quantity production by rig testing of prototypes, the rig testing often being to "iron the bugs out" more economically and rapidly than intensive field testing, which has its own special difficulties in the search for representative results.

Even on existing, proved, designs the designer cannot rest, but searches to improve them functionally, at a lower cost to the customer. These modifications are a "must" for any company that wants to stay at the top, yet this very need brings attendant risks of further teething troubles. These risks can be rashly accepted by the adventurous; or shunned, and development opportunities missed, by the cautious. Balanced judgement is difficult to maintain in this dilemma. Rig testing offers a solution by providing a glimpse of some years into the future use of a new design without recourse to a gypsy's crystal. It thus provides a welcome aid to the designer in difficult spots, and a welcome aid to the user by avoiding his being used as a guinea pig or left with machines of obsolescent design.

The advantage of Preview to the Quality Engineer. So much for the familiar design situation and its requirement for speed to give previews of service; now let us look at the familiar production situation. There is the need on the one hand not to impede the production flow and on the other hand the need to be sure that what is flowing will be correct. There are numerous cases where dimensional and metallurgical checks are not applicable, or at least require supplementary verification by rig testing for quality control purposes. The length of time required for the quality control testing of any sample component multiplied by the production flow rate, determines the size of the reserve stock that must be kept. The maintenance of a reserve stock means permanently tied up capital and permanently lost space, thus it is readily apparent that on fast flow lines, where large and costly items are concerned, that accelerated rig testing is of paramount importance. In fact, the quality engineer would like to know in ten minutes whether a transmission component will last ten years. It is to be admitted that we cannot satisfy his demands, but we shall see later how we set about this problem, using the second of the two main skills which the development engineer has to cultivate.

We have seen, then, that speed of test results is a necessity to the designer to check economic design and to keep the product up to date without the risk of service troubles. We have also seen that speed of test results is a necessity to the quality engineer to maintain production quality economically. It is rig testing that can provide that speedy result with a preview of the future, and this answers the second question posed—that is " Why is it used? "

Having so far shown " What Rig Testing is and Why it is Used," let us now move on to the next pair of questions for which we seek an answer.

The questions were " How is Rig Testing Used and What are its Difficulties? "

How is Rig Testing Used?

We shall see that it is used by increasing the speed which the test part lives. To do this there are probably two somewhat separate main skills required; one is to know how to synthesise conditions and the other to know how to accelerate results. In this part of the talk we shall examine first what these skills are and then see some examples of tests in which they are used.

The first skill, or perhaps art, of the synthetic testing is the ability to recognise what are, or are likely to be, the governing factors in the operation of the part to be tested. These can be worlds apart in character and to recognise them can often by very difficult. In one application a freak loading may be very high in some part of the assembly and close liaison with the assembly designer is imperative to ensure that the load is represented in the ultimate test plan. In another application the designed loadings may be readily predictable but some service condition may be vitally important and yet in risk of being overlooked. Liaison with a field user is important as a safeguard.

Environmental conditions should always be studied and their omission from a test should be a considered judgement of their irrelevance. An alert imagination is required too; a torpid mental approach will lead all too often to the spending of considerable time and money on a rig that, say, concentrated on exploring wear resistance properties of a component only to find that the problem ultimately met in service is one of weather corrosion. An observant eye and interested common sense should be continually exercised; there is no excuse for the development engineer who is so busy studying gear tooth behaviour that he overlooks, for example, a couple of unexpected Woodruff Key failures that were a gratuitous by-product of the main test. Every occurrence and every appearance on a rig test should be studied until its significance is understood, so that valuable clues are not missed.

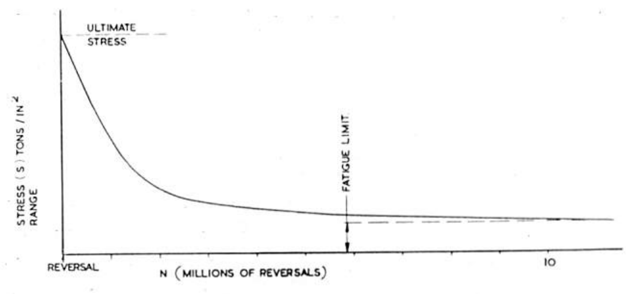
Common sense is also required, together with experience to ensure that rigs when designed apply only those loads they are intended to provide and that the conditions are readily reproducible.

We see that the first main skill is that of being able to recognise the significant service conditions from the insignificant and then being able to synthesise them in a convenient manner.

The next main skill, and as was said before, a somewhat separate one, lies in knowing how to accelerate the results. You will remember we had already seen that the speed in achieving results is as of universal importance.

The aim is to make the component under test live a full life in a short time, or to " burn the candle at both ends." It is easy to visualise the simple methods that can be employed right away, such as raising the frequency of the cyclic application of the load or condition, for example the development engineer learns to employ mechanical devices where they give speed, or hydraulic and electric devices where they are more suitable. But speed alone often changes a basic test condition by say elevating temperature or rubbing speeds, and this limitation is often reached early, so that other techniques must be sought and these also require skill and experience. We shall now go on to see first that there are conditions of fatigue failure that can be exploited, and next to examine some rigs that use this and other principles.

Fatigue Failure Acceleration. Probably the largest single principle employed and requiring skill is the acceleration of ultimate failure by exploiting the characteristics of the S.N. curve by overloading. For those not in everyday contact with this work, the S.N. curve, it should be explained, is graphic plot of the fatigue life



A TYPICAL S/N CURVE FOR STEEL

DIAGRAM III

to failure at various loads, as shown on diagram III. The S stands for stress, the N for number of reversals to failure. In general for most materials the curve is a letter "L" slightly obtuse angled and rounded to look like a boomerang, as can be seen on the diagram. This curve lies with one leg running up and towards the upright, stress axis meeting it at the ultimate stress level where failure occurs immediately and the other leg inclined asymptotically towards the horizontal or number of reversals axis, which it is roughly assumed to be parallel with at 10 millions and onwards for steels. This means that stresses at or below the level giving 10 million will never cause fatigue failure. It should be noted in passing that with aluminium the line is not asymptotic, but eventual fatigue failure theoretically can occur at very low stresses if enough cycles occur. Ball and roller bearings also have always got a finite life no matter how low the applied load. For convenience of mental picture this can be taken to be because the actual contact point area becomes smaller with decreased total load, thus the pressure loading per unit area can never be brought sufficiently low to avoid fatigue stress levels. The acceleration of failures for study purposes by applying loads which climb the left leg of the boomerang and rapidly foreshorten the test life needs to be judiciously carried out. Misleading results can be obtained, indeed there is a strong probability that the nature and position of failure may be different from those at lower loads. Experience and common sense judgement enable one to find a practicable solution in most cases, sometimes even one to find a practical means wherein it is shown that failure of one sort on a test piece is related, in life value, to another sort of fatigue in lower stress conditions. Considerable and interesting work by experts in automobile component fatigue testing has shown not only beyond doubt, but with classified quantitative ratios, that different characteristics of failure are related to the varied ratios of high and low mixed stresses a component has endured during its life.

Another feature to be recalled that is widely known, but occasionally forgotten. It is that the *range* of stress controls the cycles to failure. In rather simplified terms this means it is possible for something to carry a load of say 100 lb. on and off as often as one liked, and yet find that 60 lb. load sometimes upwards and sometimes downwards will cause failure.

Rigs Used in Exploiting the S.N. Curve Characteristics. A typical application for the exploitation of the S.N. curve properties occurs in transmission testing where a locked-in torque is used. This type of rig is known by a variety of names, "Power Recirculating," "Back to Back," "Four Square" and so on and is represented in diagram IV. This is one of the rigs where we try towards the quality engineers' requirement to learn of a ten years' life in ten minutes. Basically the system is that if any two gearboxes are placed side by side the input shafts can be geared or chained to rotate at the same speed, and (provided the same ratios are selected) so can the output shafts. If, now, one of the shafts of one box is disconnected, strained around by the desired torque loading and then reconnected, it will continue to exert the desired torque. The whole system of two sets of gears is free to rotate, however, and can be driven by a low power motor as it has only friction losses to overcome. Thus a gearbox can be made to work as if it were transmitting full power, or as much overload power as the S.N. curve and gear tooth characteristics determine as reasonable with only a small power unit driving it. This can be seen on a rig suitable for tractor transmission shown on Photograph Plate 1.

SCHEMATIC DIAGRAM OF FOUR SQUARE RIG

DIRECTION OF TORQUE INDICATED BY ARROWS

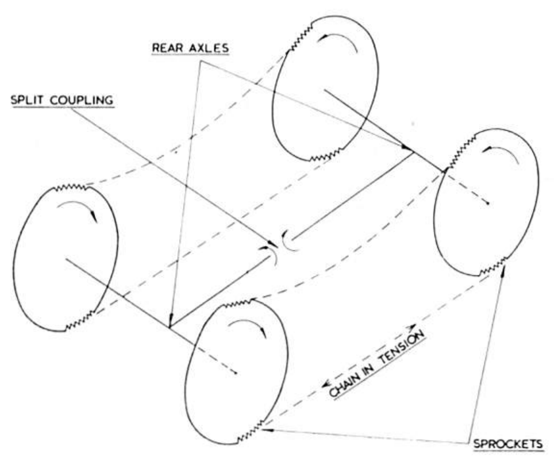


DIAGRAM IV

There are several arrangements to this system that transmission assemblies can be grouped in, and the feature that emerges is that only one gearbox can be made completely true to life with both the direction of

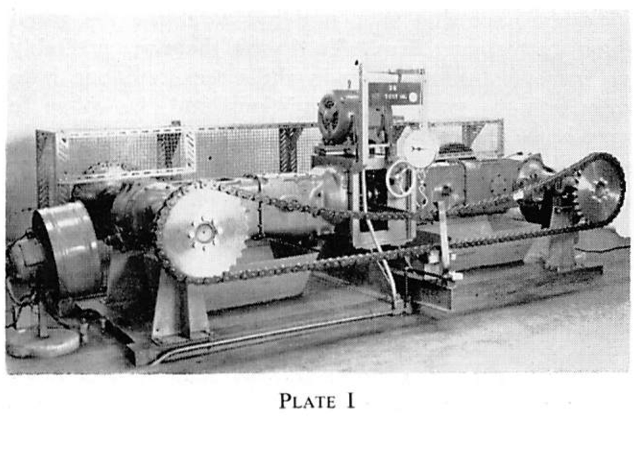


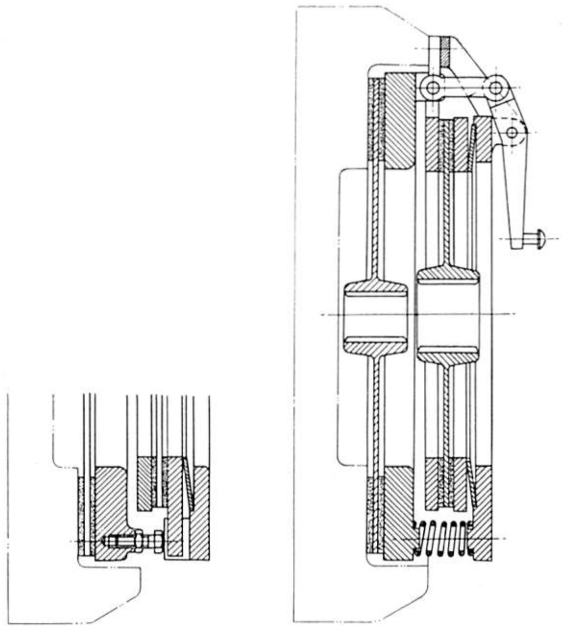
PLATE 1

torque and the direction of rotation correct. The other gearbox can have either the torque direction or the rotation direction correct, according to the arrangement selected, but not both. For general purposes it is satisfactory to arrange for the torque direction to be correct and count both assemblies as two pieces. For lubrication tests the reverse tooth flanks in one box can sometimes be used and the direction of tooth sliding kept correct. For accurate work however, one box is considered a test assembly and the other a slave box.

There is another technique in accelerated fatigue test cycling that deserves attention and that is the resonant frequency method. In this method a machine with relatively large masses is used so that its natural frequency in torsion or bending as the case may be, is barely altered by the test piece in it. Its frequency is then adjustable back to a constant for each individual test piece. A torsional machine of this type would be used, for example, to test the splined portion of a vehicle half shaft. The machine would be set in motion at its natural frequency, and the loading applied would be governed by governing the angle of twist, strain being proportional to stress. This method is not only quick but the energy used in one strain one way is stored and then used in the other direction. The only power required is that necessary to top up the internal and external friction losses in the system. It can conveniently be fed in by an adjustable length crank, rotated at the natural frequency speed. The crank being connecting rod attached eccentrically to a suitable clutch, for example an automobile hydraulic brake, causing it to oscillate on a centre bearing. A brake drum fitted over the brake shoes, but mounted to the torsional system of the rig will engage the drive acting as a clutch when hydraulic pressure is gradually applied. When the full torsional amplitude selected by the particular crank length is achieved, full hydraulic pressure stops further clutch slip. This method gives rapid testing when exploitation of the S.N. curve is otherwise impracticable for some reason.

Rigs for Other Tests. Clutch testing is an example of testing not connected with fatigue testing. The clutch on a modern tractor is an important assembly. It is worth our while to recall at least one difference between the duty demanded of it and the duty demanded of a normal lorry clutch. Such an outstanding difference is exemplified by the requirement of Front End Loader work for the clutch to be engaged and disengaged almost continually. The tractor goes in forward ao load its pick up bucket or fork, backs out to withdraw its load, goes forward to its unloading point, backs out then goes in to reload, thus completing one cycle and these cycles go on continuously for hours on end.

There is also the added complication that there is often a requirement to have a Power Take Off and Hydraulic System that can continue to operate when the transmission is de-clutched and this is usually achieved by employing a dual clutch. The power take off part is a second clutch, behind the transmission clutch and the pressure plate is lifted from engagement by continued travel of the clutch pedal beyond that necessary for freeing the transmission clutch. A typical dual clutch appears in Diagram V.



PART SECTION SHOWING P.T.O. ACTUATION.

DUAL CLUTCH ASSEMBLY.

DIAGRAM V

We have seen then that the clutch duties in a tractor are particularly arduous, and this leads on to the need for continual development testing, which is full of problems.

Clutch Testing Rig

The testing of clutches which appears in Photograph Plate II and is about to be described is carried out on a

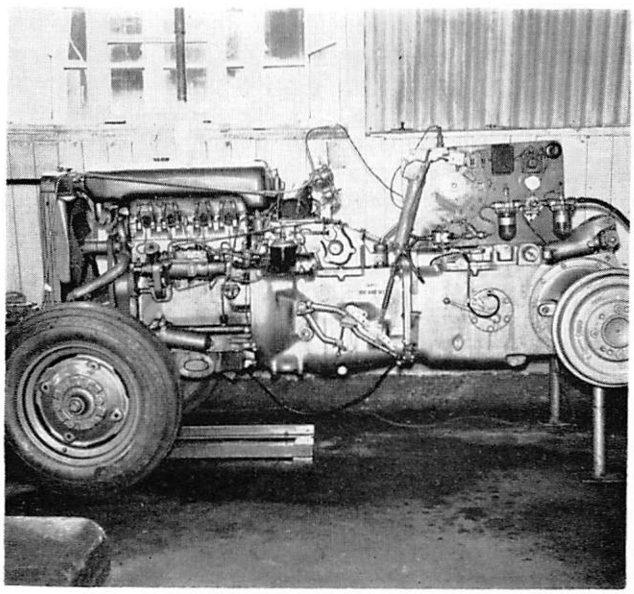


PLATE II

rig which is basically just a tractor with the back wheels locked so that they cannot rotate. With the tractor in gear, but with the clutch pedal depressed the engine is started up and the hand control set to a high engine speed. The pedal is then fully released and the clutch, gripping against the disc and thus the locked transmission rapidly slows the engine down to whatever speed we require, when a rig governor operates to depress the clutch pedal again, allowing the engine to return to high speed. This cycle is repeated at frequent intervals controlled by a timing mechanism.

In this way it will be seen that we can subject the clutch to arduous duty, and we can control both the rate of work per cycle, and the rate of cycles in a given time. To reduce the work in a cycle the lower engine speed is raised, to vary the cycles per minute the timer is altered.

The rig, *per se*, is thus very simple but the information it yields provides scope for considerable, interesting, study. The behaviour of various types of clutch facings, the heat dissipation and distribution characteristics of various types of clutch and the details connected contain enough material for a lifetime's study. Additionally to the basic rig we employ some of the more sophisticated equipment beloved of development people, cathode ray oscilloscopes, multi-channel recorders, amplifiers, strain gauges and so on to obtain data on the clutch transient behaviour during each cycle. We obtain a film from the oscilloscope and strips from the recorder that graphically give this data. We are at present regularly recording total clutch torque plotted against time, together with a signal for each revolution of the engine superimposed on the torque trace on our photographic record which uses only a two-beam oscilliscope. For analytical purposes during any unusual conditions we are able to record on the multi-channel recorder, using sensitized paper strip record, the engine speed curve (using the tractor engine generator output for our signal) the torque curve, a time base, and have room for such other signals as we may require.

This method of clutch testing is far less commonly used than are the methods of Inertia Wheels and Dynamometers. In these latter methods the measurement of work done is more easily made. Our present rig system was chosen among other reasons because it tests the clutch in its normal tractor context (that is within the bell housing) and thus provides an assessment of the air circulation and heat dissipation features which are an important feature of the clutches we employ.

The rig is employed to assess alternative clutch designs and alternative facings materials in the continuous quest for improvement and reduction in price. Tests also ensure that the quality thus developed is maintained. An idea of the success that has been achieved so far can probably best be obtained by some approximate figures giving the general order of duty that we at present consider to be standards.

The energy absorbed by the clutch during part of its test running can be as high as 6 horsepower and is relatively on " cruise " condition at 3 horsepower. If this is translated, for the sake of ready mental appreciation into terms of domestic electric fire bars each horsepower equals a modest sized 750 watt fire bar. This picture of six fire bars is staggering enough, but the actual heat generation rate during each engagement of the cycle that we employ is in the order of, say, seventy or eighty fire bars for about one second each time.

It should possibly be explained parenthetically how it is that more horsepower can be put into the clutch during a cycle than the tractor engine output. This comes about because the heavy flywheel stores energy which is then liberated together with the normal engine power during clutch engagements that decelerate the engine.

These are impressive figures, even to one familiar with the clutch, so they may also be a revelation to some who use or abuse this important assembly without thinking very much about what goes on in the bulge between engine and gearbox. The performance is an achievement of which the clutch designers and the facing material chemists and designers can be justifiably proud even though they are of course always continuing to seek further improvements.

The next step planned is the measurement, recording and analysis of the clutch work done, and the components of torque and slip comprising it, during various typical field operations. It will then be possible more accurately to simulate differing service conditions on an indoor rig.

We have now considered examples of fatigue testing and clutch testing rigs and seen how these are used for rig testing, but before leaving the subject of " How is Rig Testing Used?" let us look at a paperwork procedural pattern that emerges during testing. This pattern crystallises the ways and purposes of rig testing.

Test Procedural Paperwork

Firstly, a test schedule is found necessary. This document contains the test requirements and method. It forms the " Legal Standard," being the test equivalent to the Engineering Drawing and the Production Operations sheet; indeed the schedule number should be referenced on the drawings of assemblies that require testing. This close control of test conditions is necessary to ensure that test results remain comparable even though they may be carried out by different personnel, in different places and after long intervals of elapsed time.

There are generally three types of schedule for each type of assembly tested, these are:

(1) The Design Approval Test Schedule—This is used for exploratory test work on prototypes of brand new designs. It is started by intelligent anticipation, and developed as experience is gained.

(2) The Modification Approval Test Schedule—This is used for comparative assessment test work on samples of proposed replacement designs. It is usually based on the Design Test but embodies all the experience gained on prior Rig and Field work and is therefore thorough and accurate.

(3) The Quality Control Test Schedule—This is used to ensure that samples from manufacture continue to incorporate the key features of an already proved design. It is based on the Modification Approval Test experience, but is mainly determined by speed requirements.

We have now seen something of the second main skill required by the Development Engineer, which is to know where and how he can accelerate results, and together with his first skill in synthesising conditions we have seen " How Rig Testing is Used." We shall now move on to the difficulties of Rig Testing.

What are its difficulties?

It is to be hoped we are now agreed that rig testing is virtually a must, and is an invaluable aid to the designer, manufacturer and the user alike. The question then arises, " If Rig Testing is so wonderful, why do any problems remain? " and the answer lies in the difficulties of rig testing. We shall also in this part of the paper admit that we cannot always know what we are imitating or even what we are doing.

One apparent difficulty is that it costs money and only the larger companies have the gross product output to be able to absorb the initial rig test costs economically. A second difficulty is that the cost is more readily apparent than the benefits and not all design managements are far-sighted enough to appreciate fully the potential benefits of rig testing. A third difficulty is that some design problems are not wholly soluble by rig testing methods either because the prevailing conditions are not predictable with sufficient accuracy, or because conditions of use vary so widely that the only reliable assessment that can be made is by the " suck it and see " method, known more elegantly as " Pilot Scheme Sampling," spread out over the whole gamut of actual field conditions.

The fourth difficulty is certainly not the least, but it has been left until last because it is less palatable to admit. It is the limitations of Development Engineers and herein we find both the challenge to improve and the warning to be careful. We have seen already that test work requires the development engineer to be able to apprehend firstly the fundamental problem involved, as different from the various side issues associated (not always as straightforward as it sounds). He has then to invent a synthesising rig test that will reproduce all the essential conditions with the utmost economy of time and machinery, he has to decide the method affording the maximum practicable acceleration of rig results without upsetting the cardinal conditions. He has to be able to interpret trends and indications from the recorded results with impartial judgment, and he also has to be alert to the possible significance of some unexpected result which may provide an invaluable clue to a fuller understanding of the problem even if it means his first ideas were wrong. He should also be able to express himself lucidly both in oral and written report to ensure that all the significant test findings are conveyed to the designer and also available for future reference. Test results are worthless until they are fully and perspicuously conveyed to those people who will use them. No development engineer can ever have enough nous, learning or experience, for all the problems he would like to solve, he can only try to improve all the time. Because of this, then, we have to admit a major difficulty is formed by our own limitations, and we must learn to recognise where we must be careful. In practice this means that the development engineer should know when to be confident and alternatively when to recommend that his rig test results should be used to a limiting point only, say, to justify the manufacture of a limited number of prototypes at least until some confirmatory evidence from some other source is available as a cross check. This applies most particularly to early Development Rig Testing. Modification Testing and Quality Control Testing are usually blessed with the banister rail of prior service experience to confirm similarity of failure mechanism on the rig and in service. It can also confirm that the standard of performance considered acceptable on a rig test is suitably judged, being neither too arduous or too easy.

Some of the difficulties of rig testing of agricultural machinery have been shown and we have already shown you how rig testing is used, thus answering the second pair of questions. Perhaps we could now recall both of the two pairs of questions and restate briefly their answers.

The four questions it was our purpose to answer were:

(1) *What is Rig Testing?*—It is synthetic testing in conditions of our own choosing.

(2) *Why is it used?*—It is used to give preview answers about the future to the Designer and the Quality Manager.

(3) *How is it used?*—It is used by increasing the speed at which the test part life is lived.

(4) *What are its difficulties?*—That we cannot always know what we are imitating or even what we are doing.

The Future, What does it Hold?

Rather than conclude this talk on the difficulties of rig testing, let us take the merest glance at the trends pointing to its encouraging future. Costs will be cut and test accuracy increased as the trend to increased production volume grows. There will be rapid strides taken using the most modern techniques. Much of the development testing will become wholly synthetic and be carried out on electrical analogues, other tests will be fully automatic to achieve exact control and conserve manpower hours. The ability of the development engineer will be increased considerably by specialisation on particular problems which becomes possible when organisations grow, and rig testing, together with other branches of engineeering looks forward to challenging new times, where an imaginative mind can recognise the value of new possibilities, as techniques grow, and exploit them.

In conclusion it is hoped that some of my enthusiasm for this subject has conveyed itself to you during this talk. I should like to thank my employers, Messrs. Massey-Ferguson (U.K.) Limited for permission to give this talk to you and to point out that the views expressed are not necessarily theirs.

DISCUSSION

MR. J. F. ZISKAL (International Harvester Co. of Great Britain, Ltd.) emphasised that first it was essential to know what was being tested. For instance, if a tractor was to be tested in the field, the test group would like to push every gear up to its maximum and wreck it. But some realism needed to be put into this. One of the easiest ways was for the engineering group to tell the test group what was wanted at the start of the test. His own concern had put some electrical instruments into a tractor so that, every time a particular gear was used, it started its own hour meter. Thus, however many gears were in a transmission, it was known how often they were used. In this way they had found out the percentage of use in first, second, third—used so much for ploughing, and so on. These realistic results could be transferred to other models of tractors, and the design department could calculate how much life was needed for each gear.

It was also necessary to know about testing for deflections. One of the biggest headaches anyone had with tractors was in the torque reaction at each reduction through planetary or bull gears, and there were deflections through the entire system. How was that going to be tested ? Mr. Ziskal asked. The ideal his concern had found was to try the testing apparatus they had been shown that day, using the wheel, clutch housing and chain arrangement. But the trouble with this rig was that the pull was towards the clutch housing ; while in the field the pull was away from the housing, and weight transfer tried to pull the tractor downward. According to the vector, the weight transfer was pulled towards the back of the tractor. Mr. Ziskal continued that they had tried to bring that out in their testing, and the method they used incorporated treadmill hydraulic loads.

There was one fact about rig testing that no one could dispute, declared Mr. Ziskal. That was that there was only one item on which one got a final answer—the engine. In the rest of the machine there was the complication that someone was always going to find new implements to put on the tractor, and then it might be necessary to start all over again.

On the question of half-shafts, he mentioned an example where clutches had worn out in work very quickly, owing to the materials handling work involved. Because the fabric linings had been giving trouble, someone suggested putting in a clutch with a sintered lining. The next problem was caused by the clutch heating up. It was then proposed to use a torque converter, but they were told that it would not work, for if the axle shafts could not stand the standard torque it was unlikely that they would stand three times the normal —which would happen using the torque converter. However, when the idea was tried it worked, because the real trouble had been the shock loads in this sort of work.

He had noticed that Mr. Lang showed a device for testing the tractor clutch, using a pneumatic cylinder. That was beautiful, but Mr. Ziskal asked if it was the way a customer used a tractor, for he usually just banged in the clutch.

Concluding, Mr. Ziskal suggested that if an engineer heard about a brand new automobile on the market, and if he knew nothing about it, but that it was new and of reputable manufacture, and was then asked if he was going to buy that car, he would say : " Not until it is out for a while." Engineers would not be the first ones to buy because they had guilty consciences about how machines had been tested.

MR. P. HEBBLETHWAITE (N.I.A.E.) regretted that, although Mr. Lang had shown some very detailed and interesting work on tractor components, he had not, as the Paper's title suggested, dealt in any detail with implements. He added that, as an implement man, he felt that too often his field was neglected in favour of tractors. He did not under-estimate the need for the tractor work, but a much wider field still had to be tackled with implements as a contribution to improving durability.

The N.I.A.E. had so far done very little rig testing of implements or components, and this was a job that lay ahead of them. From their point of view, the aim would be, if possible, to test the implement as a whole, and in that connection he referred to the mention that had been made of his tractor colleagues' treadmill work. That was also an attempt to test the tractor as a whole, and obviously came after the work of such people as Mr. Lang. He thanked Mr. Lang for publishing the information in his Paper, for, in Mr. Hebblethwaite's opinion, the exchange of data of this type among manufacturers and such organisations as his own was valuable and had not been done sufficiently up to the present time.

Probably the biggest initial task on the implement side was the determination of the spectrum of stresses encountered in the field. Reference had been made to the work at M.I.R.A., which showed that if a complex stress spectrum was encountered in the field, this had to be simulated in a rig, not just replaced by repetitions of a single stress level. This complicated rig testing.

To stimulate discussion on implements, Mr. Hebblethwaite posed two hypothetical questions. The first concerned the conveyor chain on the bed of a manure spreader. He asked if, when rig testing that chain, it was necessary to reproduce its chemical environment as well as its mechanical one, and if it was thought necessary by Mr. Lang to apply a complicated spectrum of loadings. Secondly, for rig testing pick-up tines, as used on balers, was it necessary to adopt a complex spectrum, or would one stress level repeated many times suffice ?

Then Mr. Hebblethwaite showed some slides, including one of the N.I.A.E. treadmill, in which the rear wheels of the tractor were standing on a grit-surfaced steel track. Power was provided by the tractor engine, and drawbar pull and other measurements could be made. The virtue of using a treadmill was that one could programme the test and, independent of weather, simulate a large number of field hours in a very few weeks. He had been interested in what Mr. Ziskal had said about the number of hours worked in each gear ; in this context it might be as well if everyone doing this type of work used the same programme to make results more comparable.

Another slide showed load fluctuation in the field—torque/time traces for five different forage harvesters.

Describing research being done at the N.I.A.E., Mr. Hebblethwaite referred to work on soil/metal wear, saying that this should eventually lead to an effective rig test for this property of metals and provide a more useful long-term answer than the comparative field tests currently used.

MR. LANG, in answering Mr. Ziskal, agreed that his criticism of the four-square rig was valid—the deflections were wrong. An approximation of the magnitude of the chain load could be made, but the vectors could not be altered. However, the final reduction gears with which his company was concerned were epicyclic and symmetrical around 360 degrees. The vector direction problem was thus evaded, whilst the vector magnitude was arranged for in the selection of chain wheel sizes. His company had done this test because it was easy, and Mr. Lang could think of several applications where it might have been valuable. He was not really an expert on engine rig testing, he asserted, but recently he had read a Paper by an oil company in which it was said that engines could not be properly tested on a rig because the conditions of use varied so widely. He gave such examples as using the engine in a laundry, for fleets, or in a taxi service.

His company had also experienced difficulties with clutch facings. They had found a beautiful facing which would not work in service, but they had been cautious and used a pilot scheme—which was the admission of defeat for a rig testing engineer.

He was aware of the criticism of their work on half-shafts and agreed, but the rig shown was for product development, and they would have used a different one for other purposes. Had they been in service trouble they would have changed their approach, paying detailed attention to spline engagement, etc. ; programme loading was an art of its own.

Mr. Lang said he had enjoyed Mr. Hebblethwaite's remarks, as well as Mr. Ziskal's. There was a shortage of information about implements. One reason was volume of production. As the production of implements was usually on a smaller scale, the justification for rig tests was small, and relatively few rigs were made. It was true that, while he had not shown it in the slides, in the written Paper an implement rig was described for testing the disc bearing. Another reason why he had not said so much about implements was that he had not worked as much with them, and had tried to keep to the work he was more associated with. He agreed that implement testing could well employ rig testing techniques.

He spoke of the need for co-operation between the rig tester and the field tester. The former could be parochial and end up thinking it was his job to test rigs ; he needed someone to keep his feet on the ground. A person in the field could tell the rig engineer what the loads were in practice, but it was a skilled task to describe field conditions properly.

To Mr. Hebblethwaite's two questions, Mr. Lang said that he did not know the answers to the need for environmental and shock load simulation in testing the manure spreader. He could, however, give his guesses. He would have thought that environment was important and it would certainly need to be considered. There might even be stress corrosion. Perhaps it was enough to consider abrasive wear and not to worry too much about shock loads. There was an easy answer to the question on pick-up tines. Someone where he worked had decided how to do it. He just thumped them ! If they stood up to that for a number of cycles at high loads they seemed to be all right. It was a modification approval test.

Mr. Lang was interested in some applications of the N.I.A.E. treadmill, but he felt it was neither flesh nor fowl. It was virtually a field test in its present form, and he would want to complete its transformation into a rig test. Tyre adhesion was the factor limiting treadmill transmission loads, and this precluded one of rig testing's most important accelerators—exploitation of the S.N. curve characteristics. On the other hand, he liked the idea that was employed with the treadmill of programming the work.

He asked Mr. Hebblethwaite about the time scale in his forage-harvester graphs, because he thought it was wrong. He wondered what would be the result if the work were done on a short-time scale.

Mr. Lang emphasised that the instrumentation of field conditions was a special art, and without it rig tests in the past had been wasted. The more good results that came back from service the simpler the rig tester's job became. At the present he had to guess what instrumented results would have been.

MR. J. M. CHAMBERS (Warwicks.) wanted to make one or two comments before he asked his question. He thought Mr. Ziskal's example of the brand new automobile did development engineers an injustice—had he forgotten the production engineers who came between them and making the product available ? Mr. Chambers said he also had been going to ask about the scope for testing implements, because he felt that they could do more and more to improve implements by rig testing.

He wished to ask why some mention was not made of radio-active components in test pieces. It was becoming more and more part of rig testing, particularly in engines and transmissions and other components, and enabled one to obtain readings as wear occurred. Mr. Lang had said there were some parts one cannot rig test and had taken as his example a watch. However, Mr. Chambers thought that if radio-active components were assembled into the watch and a stream of filtered air was blown into the watch results could be obtained ; so perhaps nothing was impossible to rig test.

MR. LANG, after agreeing about the scope for implement testing and adding that it was to be regretted that he had not included more about it, went on to say that the reason for the exclusion of radio-active work was the same as that for implements ; he had not had experience of them himself, as it was done elsewhere in his company.

MR. H. C. G. HENNIKER-WRIGHT (Ford Motor Co., Ltd.) congratulated Mr. Lang on his Paper. One point that needed qualification was Mr. Lang's remark that there were three types of schedule ; Mr. Henniker-Wright would have said there were four, the last one being a schedule dealing with service complaints. His company had done a lot of work on a clutch test machine similar to the one described and found, like Mr. Ziskal, some difference in results.

MR. CHAMBERS asked if Mr. Lang would care to give some idea of the life increase obtained through rig testing pinions and pin gears.

MR. C. HUNT (Massey-Ferguson, U.K., Ltd.) desired to encourage Mr. Lang to write another Paper, entitled " Some of the Pitfalls of Rig Testing," and illustrate it. Rig testing was often loosely spoken about. If a designer was relying on a rig test engineer to develop a machine, then he was not doing his job. He thought in the future it should be possible to reduce weight and use higher stresses because of the information provided by rig testing. The various institutions should collaborate on this because there was much duplication in this kind of work. A lot of fundamental information was kept privately by various firms, and the institutions should suggest fundamental research to be done by the large firms which could carry out rig testing.

MR. LANG concurred with Mr. Henniker-Wright's comment about service schedules. To give Mr. Chambers figures would be misleading, he declared. It was certainly true to say that the rig life of these components had gone up from, say, a unit of 10 to one of 50, although he was not sure what the practical aspect of this was. The service experience seemed to support these results.

THE PRESIDENT stated that he did not intend to sum up, but that he had one comment, because Mr. Hebblethwaite had not had time to reply. This was about the doubt cast by Mr. Lang on the treadmill at the N.I.A.E. The tractor shown in the slide had done 1,000 hours' work in a week, and the gearbox had operated for 300 hours in second gear. The value of the treadmill test was that you could get good repeatability, and it was a controlled test which one could not get in the field, although the point about tyres was valid. He thought Mr. Lang had performed a valuable service by showing that rig testing engineers had a useful contribution to make, and he thanked both the speaker for his excellent Paper and those who opened the discussion, Messrs. Ziskal and Hebblethwaite.

A New Course for an Ordinary National Diploma in Agricultural Engineering

As from September, 1962, Rycotewood College will provide a two-year residential course for the Ordinary National Diploma in Agricultural Engineering. Full particulars may be obtained from the Principal, C. A. Goodger, C.I.Agr.E., Rycotewood College, Priest End, Thame, Oxon.

Royal Show, Newcastle

The Secretary will be attending the Show on Tuesday and Wednesday, July 3rd and 4th, and will be available on Stand No. 58, Avenue F (*Farm Implement and Machinery Review*), through the courtesy of Messrs. Morgan Brothers (Publishers), Ltd., and the Editor, Mr. W. J. Priest.

MACHINERY FOR THE IMPROVEMENT OF GRASSLAND

by W. Ellison,* B.Sc., Ph.D., J.P.

A Paper presented at an Open Meeting on 13th February, 1962

INTRODUCTION

WHILST the plough is undoubtedly the implement *par excellence* for grassland improvement under many conditions, there is a wide variety of other circumstances where its use would be either impossible or inappropriate, and almost certainly uneconomic. It is here that other machines and implements may have a special part to play in grassland improvement. Such machines may themselves be used in grassland improvement over a wide range of conditions, but they may also have an important part to play in the subsequent maintenance of swards improved by ploughing. Thus there are three sets of conditions under which these machines might be used :

1. Where it is impossible, inappropriate or uneconomic to plough.
2. Where either machines or the plough can be considered as alternatives.
3. Where the machines can be complementary in their use in relation to the plough.

At this stage it might well be asked why have these implements and machines, other than the plough, not played a greater part in grassland improvement during the past twenty years or so ?

This question can be answered briefly from two points of view—one economic, the other agronomic.

Economic. Government policy has in numerous ways been designed to bring more grass under the plough and to use the plough as a means of stimulating production from both tillage and grassland since 1939.

Agronomic. Against this background, it has been relatively easy to make out agronomically a strong case in favour of the use of the plough, since it is the most effective means of getting rid of the original vegetation and thereby reducing to a minimum subsequent competition with any sown species.

Even so, there are many who would rightly claim that there are still millions of acres of grassland in this country which could be greatly improved by either method.

What then are the prospects of machines, other than the plough, being used for the improvement of grassland in the future ? As in the past, the answer to this question will in the main be based on economic and agronomic factors.

With regard to the former, it may be relevant that low cost rather than maximum production is the order of the day. One must, however, distinguish carefully between low cost in terms of small capital outlay and low cost in terms of cheapness or low cost per unit of production.

Grassland improvement through the use of the plough, especially in the case of direct re-seeding, requires a relatively large outlay per acre treated and frequently needs extra capital for additional stock. Nevertheless, the increased production may ultimately prove to be the lowest in terms of cost for each extra unit of production. Grassland improvement by other methods does not usually require such high initial outlay in terms of work done or extra stock, but if the resultant increased production is small then the cost per unit of extra production may well be relatively high.

It is therefore the extra cost per unit of extra production that is of overall importance in grassland improvement. This will be dependent not only on the technique used, but also on the farmer who is applying it, as well as the circumstances under which it is being applied. High cost methods such as ploughing and re-seeding can give outstandingly good results in the hands of a competent farmer, if applied under the right conditions. Such methods in the hands of less competent men can, however, be disastrous and may well prove to be a first-class means of losing money rather than making it.

Methods of grassland improvement based on means other than the plough may well have a place under a wider range of conditions in the future than in the past because of changing economic conditions in which capital is likely to be in shorter supply and profit margins more meagre than at present.

On agronomic grounds, these methods must undoubtedly result in some improvement in both quantity and quality of production if the expenditure involved is to be justified. Some would agree that this can only be achieved if the methods employed can bring about a marked change in the species composition of the sward concerned. This may be done either by stimulating any better species that might already be present or by the introduction of better species into the sward by some means or other.

This whole proposition of the need to materially change the species composition of even the so-called poorer permanent pasture types is a debatable one and one which many competent farmers and technicians would, in fact, deny. Be that as it may, however, the point remains that all would agree that such pastures are capable of greater and better quality production through the greater use of fertiliser sand lime, even without marked species changes.

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It is only against this sort of economic and agronomic background that further examination of this topic is justified in relation to the machines and techniques now available to the British farmer.

Some of the principal types of machines available for grassland improvement under British conditions may be listed and grouped as follows :

- Group A. Chain harrows, various types of spiked and tined harrows, disc harrows and certain modified cultivators.
- Group B. Rotary cultivators.
- Group C. Sod seeders.
- Group D. Mowers and cutters of various types.
- Group E. Miscellaneous machines such as bracken crushers and even mole ploughs or sub-soilers.

Before discussing the use of these machines in detail, it might be useful to examine some of the grassland types and conditions that require to be improved.

THE IMPROVEMENT OF GRASSLAND BY MACHINES

Machines can generally be used on all ploughable grasslands, but in addition they may be suited to a much wider range of conditions. In general, the grassland types or conditions which they can be used to improve might be classified as follows :

1. Leys or other re-seeded grasslands which are declining in productivity.
2. Permanent pasture of low producitivity, regardless of whether or not it is ploughable.
3. Rough grazing land, especially that which is unploughable or should not be ploughed. Such areas may be dominated by one of the following types of vegetation :
   (*a*) Bracken.
   (*b*) Nardus or Nardus Fescue.
   (*c*) Molinia.
   (*d*) Heather.

In relation to these grassland types and the machines available for their improvement, it might be as well to consider what is required of the machines under these conditions.

Grasslands of the types mentioned above are usually low in effective productivity and nutritive value for one or more of the following reasons :

1. The low fertility level of the soil.
2. The low nutritive productivity of the indigenous species.
3. The presence of a surface mat which may be associated with a root mat. The mat itself is symptomatic rather than causal, and usually signifies acidic soil conditions, coupled with a low level of microbiological activity.
4. The absence or relative scarcity of a suitable legume, such as white clover in the sward.
5. Superabundance of weeds, especially those of the rosette type, which, coupled with an unduly high proportion of bare ground, is typical of many declining leys.
6. Poor drainage and soil conditions, together with a predominance of rushes or other species typical of such conditions.

Apart from drainage, machines for the improvement of grassland should be able to counteract the characteristics set out above. In particular, such machines should be designed to achieve the following objectives :

1. Bring about soil conditions in which fertilisers can be effectively utilised by the sward. This will necessitate the disposal of any mat and an improvement in the condition of the soil where it has suffered from excessive trampling and poaching.
2. In certain cases, bring about the removal of a substantial proportion of the indigenous species and provide a reasonable percentage of bare ground in such a state that better species can be successfully established in the sward.

The prospects of achieving these objectives are brighter now than at any time in the past, for the following reasons :

1. An adequate supply of tractor power is now available on most farms.
2. There is now a better range of suitably designed machines to match both the power available and the problems to be solved.
3. A wide range of selective herbicides is now available which experience has shown can play a valuable complementary part to certain types of machines in many grassland improvement projects. Such herbicides can, in fact, be used by themselves on a selective basis or be combined to give a complete kill of all herbage in many swards—a technique now popularly referred to as " chemical ploughing."

THE PLACE AND USE OF MACHINES IN GRASSLAND IMPROVEMENT

Group A. Various Types of Harrows, including Disc Harrows and Modified Cultivators

The general effect of the machines in this group is that of spreading and scattering with varying degrees of penetration into the sward and surface soil, depending on the weight and type of the machine. Consequently, such machines are useful in spreading muck, animal droppings, mole and ant hills and in helping to eliminate the effects of poaching and trampling. This group of machines is mainly suited for work on various types of declining leys and some permanent pastures, being of little value on any of the rough grazing areas, except possibly on heather areas after being burnt. They may also have a special part to play in improving wet clay heavy land areas which have a tendency to become dominated by rushes once they have been ploughed and re-seeded. Through the use of these machines the majority of the buried rush seeds remain undisturbed, and sward improvement can be achieved without a heavy invasion of rushes.

Where there is a fair proportion of bare soil, as often happens in the poorer leys, the heavier machines in this group can be used to penetrate the surface soil and break up any capping that may have occurred. It may even be possible to produce some sort of tilth into which some cheap but better seeds might be sown. Similarly, on matted permanent pastures these heavier implements can be used to tear out the mat and open up the surface of the sward and bring it into a state whereby there will be a more ready response to any lime and fertilisers that might subsequently be applied. In general, however, the composition and quality of produce from a sward treated in this way will tend to remain unchanged, although its total productivity may be very considerably increased by the combined efforts of surface treatment and the application of lime and fertilisers.

Groups B and C. Rotary Cultivators and Sod Seeders

Attempts to devise machines by means of which it would be possible to deliberately introduce new species into a sward without ploughing have followed two broad lines of development. They are :

(*a*) Some type of rotary cultivation.
(*b*) Some system of sod-seeding.

Group B. Rotavators

Rotary cultivation can be an effective means of killing off existing herbage while at the same time mixing any surface mat or trash with the top soil and ultimately providing a seed-bed of varying degrees of fineness, depending on the number of operations carried out.

Developments within the general group of rotary cultivators in relation to size, weight and method of attachment have increased their adaptability to a wide range of farming requirements, though some farmers may still experience difficulty in matching their tractor p.t.o. power to the requirements of particular machines.

A machine of this type has now been adapted to produce relatively narrow alternate strips of rotavated and undisturbed ground, each approximately 10–12 ins. wide. It is not clear how grass and clover seeds would best be sown into the rotavated strips, but this should not present any unsurmountable difficulties. Another idea being developed by Cuthbertson and reported by Smith† is based on the " Rotoflail," originally derigned to chop us straw left behind by a combine-harvester. It is believed that the knives of this machine could be used to chop up the herbage " so finely that it is blown by the wind, leaving an open sward in which the seeds can germinate." In this connection, however, it is worth noting that very little precise plot work has so far been carried out in this country on the use of the rotavator as a tool for grassland improvement.

Group C. Sod Seeders

Work at various centres in this country has recently been carried out on the technique now popularly known as sod-seeding—a technique which seems to have been successful under certain conditions in both the United States and Australia. In both countries the results seem to have been best on range or pasture conditions with sparse indigenous vegetation in the low rainfull areas. Under such conditions new species can, apparently, be successfully sod-seeded into the existing herbage prior to the advent of favourable growing conditions. In this way the newly-sown species suffer a minimum of competition from the established plants of the existing sward, which themselves will have to re-start growth from " scratch." Competition is also much less than would be experienced under British conditions because of the open and sparse nature of the existing sward. Most of this work abroad has been successfully carried out using seeding units based on a type of coulter, which makes a channel or slit into which the seed and fertiliser are sown.

Under British conditions it is extremely doubtful if the slit type of coulter will give equally satisfactory results, for the following reasons :

1. Penetration into the sward is difficult to achieve, as also is control in terms of both width and depth. This is true of most other types, but can be more disadvantageous in the case of a slit than a furrow.
2. Most slits of this type tend to close up and " heal over " surprisingly quickly, so that many seedlings are smothered or checked and die off in the early stages.
3. Any new seedlings are likely to suffer from severe competition from the existing herbage, which will soon form a canopy over the slit unless kept in check by very close grazing. Competition of this kind will be greatly accentuated by the application of fertilizers " down the spout " with the seed.

Because of these difficulties, we at Aberystwyth have preferred to concentrate on a skim type of coulter with a view to removing a ribbon of turf about 2 to 3 ins. wide and 1 to 1½ ins. deep.

Even with this type of miniature furrow the new seedlings can suffer severely from competition from the existing herbage unless it is kept reasonably closely grazed. We regard the type of machine illustrated by these slides as still very much an experimental prototype and one on which many more refinements still need to be carried out. In particular, we would like to be able to give better coverage of the seed and if possible ensure that both seed and fertilizer were mixed with a little soil at the time of sowing. At this point, however, it might be useful to explain some of our general views on the possible use of the sod-seeding technique under British conditions.

These might be summarised as follows :

1. When we first started working on this technique some ten or twelve years ago it was felt that it might be a useful means of rejuvenating leys after they had passed their best, but before they had reverted too far to the poorer grass species such as " Bent " or Yorkshire Fog.

We have always regarded it as a " rough and ready " technique by which both seeds of better species of grasses and clovers, as well as fertilizers, could be cheaply injected into a declining ley to sustain and prolong its productive life.

In those early days it was not visualised as a technique for sowing better species into natural hill swards or old permanent pastures in the lowlands in association with herbicidal treatments. Nevertheless, the use of this technique under these conditions may become a practical proposition.

2. More recently we have become interested in the possibility of using the sod-seeder as a means of sowing other types of farm crop plants into a sward for special grazing purposes, usually prior to ploughing up the sward. For example, it seems that either kale or rape can be successfully established in this way, especially if growth of the existing herbage is checked with a suitable herbicide. Under these conditions, slugs can be a surprisingly serious pest, and precautions may have to be taken for their control. In this way, it may be possible to provide additional late autumn and winter grazing cheaply under conditions that will be less susceptible to damage from treading and poaching than if the land had been ploughed and cultivated in the ordinary way.

Winter cereals such as barley, wheat and rye have also been sown into swards to provide either an additional autumn grazing (or cut) or an early spring bite. It is as yet too early to say how successful these particular applications of the sod-seeding technique are likely to be. From an agronomic point of view, however, it seems likely that where herbicides are used it will be easier to establish such plants as kale, rape and winter cereals than ordinary grass or clover species, especially when there is a dense existing sward.

Subject to costs and the efficacy of herbicides, it does seem that "chemical ploughing" may well become complementary to many of the surface methods of grassland improvement already discussed. In particular, it is possible that "chemical ploughing" may well go "hand in glove" with sod-seeding, the herbicides being applied over the whole area or else applied in bands on either side of the strip of ground being sod-seeded. In a similar way, the application of herbicides might be combined with the use of a rotary cultivator designed to treat alternate strips so as to kill the rotavated herbage, thereby further reducing the competition to the new seedlings.

So far as both of these types of machines—rotavators and sod-seeders—are concerned, it is as yet too early to say exactly where the possibilities of either or both will fit into any schemes of grassland improvement. There may well be a place for both, but the particular conditions under which either is appropriate remains to be determined by further experimental work.

Group D. Mowers and Cutters, etc.

The machines in this group differ functionally from those already discussed, in that they do not have any direct scratching or disturbing effect on the sward or the soil, nor on any mat that might be present. Neither do they directly prepare the sward to receive fertilizers or seed. On the other hand, they can be used to reduce or even eliminate certain undesirable species by a process of exhaustion through cutting at appropriate times. Even more important, they may be effective in increasing both the palatability and the nutritive value of herbage where, due to the system of grazing management, it would generally become coarse, tufted, fibrous and unpalatable. The beneficial effects of using these machines are therefore :

1. The reduction or elimination of undesirable species, such as thistles, rushes or bracken.
2. Improvement of the quality of the herbage by keeping it in a young and leafy condition, as well as by removing any that is coarse and tufted.

Although the topping of pastures has long been advocated as a good practice, it is one that is seldom carried out these days. Whether this is due to lack of faith in the value of the job or because of some other reason is difficult to determine. It is, however, generally believed in some quarters that the present-day mower is not really suited to the job of pasture "topping." It works at too high a speed and is too lightly built, so that when just running through light stemming material it tends to "knock itself to bits."

Whether or not this is true is a matter for debate, but if it is then it is a case of having to decide whether it is better to modify existing machines or ask the farmer to buy yet another machine to do the job.

On the other hand, the gang mower now seems to be establishing a place for itself as a valuable aid in grassland management in some areas. Here its chief function, as previously mentioned, is to remove surplus growth and keep the herbage young and leafy. There are other types of machines which will do this job equally well.

In this connection one is tempted to wonder if in some of our gently sloping grassy hill and upland areas there is not a place for some cutting type of machine which would give a beneficial effect, equivalent to that which is said to result from cattle grazing these areas. Under such conditions many claim that it does not matter if the cattle are not very profitable themselves because they do so much good in improving the grazing for the sheep.

So far as I know, no experimental work or trails have been carried out to study and compare the benefits of machine mowing as against cattle grazing—both with lime and fertilizer treatments—in relation to any consequential benefit to the sward or the sheep grazing it. It might be worth a trial somewhere some time ! This group of cutting machines has probably as great a part to play as any of the others under discussion in the future of grassland improvement, provided they can be properly integrated into a sound system of grassland management.

Group E. Miscellaneous Machines (*i.e.*, Bracken Crushers, Sub-Soilers)

Brief mention is made to these two machines because they illustrate two interesting but contrasting ways that can be used to control a serious weed plant—bracken—covering large acreages of our rough grazing land.

Most people are familiar with the various types of bracken crushers or bruisers, and readily accept the principle that, provided the treatments are carried out adequately, the bracken will eventually die out through exhaustion.

Fail‡, however, has shown that bracken can also be effectively controlled by the use of a sub-soiler. In this particular experiment a sub-soiler was pulled by a wheeled tractor through bracken 5 ft. high to burst through the rhizomes 15 ins. deep with cuts at 14 ins. apart. " The standard 12 in. disc coulter on the sub-soiler was replaced by one of 20 ins. in diameter to allow a deeper cut and so prevent broken rhizomes blocking round the sub-soiler leg."

This work was carried out in the North of England and was shown to be most effective if the sub-soiling was done during early August. This particular experiment needs to be carried out over a number of years, as it is believed‡ that, when successful, the bracken dies through desiccation of the rhizomes and, of course, this may not occur in all seasons, especially during a wet August. At the same time, this particular method has much to commend it because it is relatively cheap and can be carried out by the farmer himself without the use of special equipment or the aid of a contractor. Furthermore, as emphasised by Fail‡, this method entails no loss of grazing, no risk of erosion, and the quality of the herbage after the bracken has died can be quickly improved by the liberal use of lime and fertilizers, combined with some form of surface seeding. Improvement will, of course, be much slower than if the land has been ploughed and re-seeded. In this connection, it should, perhaps, be pointed out here that while these two methods, crushing or bruiser and sub-soiling, are in the main only suited for land relatively free of large stones and boulders, they can be used on many areas which are too steep or difficult to plough.

FERTILIZER DISTRIBUTORS, SPRAYERS AND DRAINAGE MACHINES

It has been quite impossible in the time available to say anything about these types of machines. Nevertheless, they have a vital part to play in many programmes of grassland improvement. Scope undoubtedly still exists for their improvement and modification to meet the differing needs of farmers and farming conditions in various parts of Britain.

THE FUTURE

In spite of the many omissions in this Paper, I hope it will provide a basis for a lively discussion of the issues involved.

Before concluding, however, I would like to spend a few moments looking into the future, not that I would claim to have a better crystal-ball than anyone else—probably worse, in fact. But I feel someone is going to be quite justified in asking what is the future of these machines in the improvement of grassland.

Any attempt to answer this question can only be made on the basis of assumptions, some of which might be listed as follows, regardless of the Common or any other market !

1. That less and less land will be kept under tillage and that the plough will tend to move less quickly about or around the farm (this will be especially so if the ploughing grants are abolished).

2. Cheap grass will continue to be the basis of sheep and cattle production (including dairying) in this country.

3. The usage of fertilisers and lime will continue to increase on our enclosed grasslands as the most economic and effective means of maintaining production.

If these three assumptions are sound, then it is likely that the various types of machines discussed in this Paper will have a greater part to play in the future than they have in the past in improving or sustaining grassland production. This would be especially true if any reduction in the use of the plough resulting from the removal of ploughing grants were accompanied by a change to some form of financial aid to meet the cost of surface treatments. One might be tempted to indicate which machines are likely to be used more in the future, but I think this would be better avoided because, as has already been indicated, it is impossible to dogmatise as to which machine is likely to be best under any particular set of conditions. What is much more important is that both the farmer and his adviser should know just what they want the machine to do and to be equally sure that the machine they propose to use will do just that. It is, however, in this connection useful to remember that any resultant improvement may either be an end in itself on unploughable areas or it may be a very valuable form of pre-treatment on areas to be ploughed at a later date. In any event, the ultimate objective of all methods of grassland improvement is the same—to enable grass to play an increasingly important part in producing British milk, beef and lamb at prices that will be competitive with overseas supplies.

REFERENCES

† Smith, C. S., (1960) *World Crops*, Vol. XII, No. 9, pp. 342–344.

‡ Fail, H., (1956) *J.Agric.Engng.Res.*, Vol. I, No. 1, pp. 68–80.

DISCUSSION

Mr. J. O. Green (The Grassland Research Institute) remarked that he thought the Paper such an excellent review of the subject that there were not many gaps to fill in.

Professor Ellison had dealt very fully with " surface " treatment of pasture. Mr. Green wanted to take the guidence a little " deeper "—too little was known about the root in its exploration of the soil. As the Professor had tacitly indicated, a pasture could be no better than the soil on which it grew. Some not-altogether-respectable grasses could be quite productive on a good soil, but the reverse was not true. The existing vegetation of an unproductive pasture might be killed and so-called " better " species introduced, but unless the soil was improved those species would not thrive, and the turf would usually revert to its former composition—of plants that could tolerate the poor soil condition.

He asserted that a soil had to be judged both by its chemical properties and by its physical condition. Experimentally, much attention had been given to chemical deficiencies of soils and relatively little to physical deficiencies—yet deficiencies in the availability of plant nutrients were often largely a function of physical conditions. There was much experimental evidence to show that additions of nitrogen, phosphate and potassium would improve the productivity of almost any pasture, regardless of its composition. It was also clear that, with continual inputs of these fertilisers, good species could be maintained in a productive state on almost any soil of adequate pH. But the input of nitrogen, phosphate and potassium required would be very much smaller if those nutrients circulated effectively. For this to happen, the dead herbage and roots had to decompose quickly. On siliceous soils, lime might be a limiting factor in that process, but everywhere good aeration was essential. It was just as essential for decomposition as for the functioning of living roots. Superficial cultivation, with lime if need be, would go a long way towards preventing the accumulation of a dead mat or "sod," and towards releasing plant nutrients for new crop growth.

But the grassland problem went deeper than that—literally. Poor aeration, or even mere compaction of the lower soil horizons, inhibited root development and restricted the uptake of water and nutrients, particularly in the summer. Poor aeration might simply be owing to the texture of the soil, or might result from bad under-drainage and water-logging. Clay subsoils, with poor fissure development, old plough pans and other impediments, all called for more radical mechanical treatment. Subsoiling might be enough, though moling and/or tile drainage might also be called for.

Experiments on subsoiling were poorly documented for grassland, but Mr. Green was sure that there were many many acres of old turf that would benefit from thorough cultivation at depth. He ventured to suggest that, while the modern, deepish style of ploughing might not always be 100 per cent. effective in killing old turf, the reseeded ley derived great benefit from the improved aeration of the whole of the top soil. This was something that the rotary cultivator, as used for surface fallowing and seeding, did not provide, and something that sod seeders and "chemical ploughing" could not produce. If those superficial techniques were used on the types of soil he had been referring to, he thought they must be accompanied by some form of subsoil cultivation. Some such combination of surface treatment with subsoiling might have some weighty advantages over ploughing—and not only economic ones. On many grassland soils the top inch or two of soil had by far the most stable structure. It was desirable to retain that material at the top to resist the effects of rainfall and treading. He considered that a great many reseeds deteriorated because of the instability of soil brought to the surface by ploughing. Much of this country's poorer grassland had a shallow top soil, and there were some subsoils which obviously ought not to be brought to the surface. In other situations there might be other reasons for not inverting the soil. Professor Ellison had quoted the example of land infested with buried seed of rushes. It could also be demonstrated that the ploughing down of an acid mat could lead to impeded drainage and very poor root development.

The plough might well be on the way out as the best means of killing old turf. With reasonable weather conditions, a rotary cultivator could be just as effective, if not more so; and chemical methods of killing plants were rapidly superseding mechanical methods in various spheres. It seemed to him that, in addition to the points that Professor Ellison had raised, they could usefully discuss effective and cheap methods of relatively deep cultivation which might be applied to (*a*) live turf, and (*b*) dead turf due for over-sowing.

MR. W. E. CAVE (W. E. & D. T. Cave) thought that the most important "implement," if it could be called an implement, for grassland was the grazing animal itself. Insufficient emphasis had been placed on this, but he could understand that at a gathering such as this, animals were rather frowned upon. Fencing was also important, and fencing and the animal were quite as important as any machinery.

A year ago, Mr. Cave would have agreed with practically everything that had been said, but during the past year he had had much experience with a rotary cultivator in a fairly narrow range of soils ; he was not sure if it applied to all types of soils. For some years he had used a rotary cultivator on peat, which was difficult to plough. But the machine had cut up the peat into 2 in. cubes and subsequent rotary cultivations had only stirred them around without reducing their size. These cubes had dried out and the grass seeds had only been able to grow in the cracks between them.

This year, however, he used a 60-h.p. tractor with two gearboxes and a bottom gear speed of only one mile per hour. At this land speed, using a high rotor speed, the old mat and peat was shredded, as opposed to cutting it into cubes. This produced a sponge-like mass, which only dried out to a depth of about ½ in. He confessed that it looked a very unsatisfactory seedbed, but, in fact, the seeds had germinated very well, particularly in the wheel tracks of the tractor which pulled the roller. The wheel effect was so obvious that he rolled it all four times, taking care to drive the tractor so that all the land was actually rolled with the tractor wheels. Whether the roller which it pulled had done any good at all he could not say !

Where it proved possible, they burned off the old vegetation before rotary cultivating, but when, owing to the green growth, it was impossible to burn the gorse and heather—which had been up to 2 ft. high—one rotary cultivation pulled it up and smashed it, leaving it on top of the ground, where it dried out and burned readily.

He had been amazed at the complete kill of gorse, heather and natural grasses obtained by rotary cultivating. It was, of course, too early to tell if re-growth would take place in subsequent years.

There appeared to Mr. Cave to be six main advantages of rotary cultivating compared with ploughing. The first was that the lime and phosphates could be put on well in advance of starting cultivations, whereas with ploughing it must be put on after ploughing and before the subsequent cultivations. Second, the lime and phosphates were well mixed with soil, where the plant could make use of them. Third, the top 2 ins. of soil contained practically all the natural fertility, and if this was ploughed down to a depth of 6 to 10 ins.—and in many cases it had to be deeper—that fertile top soil was lost to the seedling plants and probably until the land was ploughed again. Fourth, on a heavy clay soil the plough turned up a stiff intractable clay which was very difficult to work down to a seedbed ; rotary cultivating left it alone. Fifth, rotary cultivating had a much greater levelling effect than ploughing. Lastly, rotary cultivating brought stones to the surface much more than ploughing, and they could then be picked up if this was desirable.

He remarked that, under favourable conditions, a 50-h.p. tractor and a 6 ft. rotary cultivator could cultivate in bottom gear at one mile per hour, about 5 acres in an 8-hour day. Subsequent rotary cultivations could be done at double this speed. These cultivations would leave the land in excellent condition for sowing grass seeds. How this would compare for cost with other methods he could not definitely say, but, except on very easily worked land, he thought it might well be cheaper than ploughing. It seemed to him that rotary cultivation left the seedbed more hollow than ploughing, and care must be taken not to poach the land when it was first stocked. He had only used sheep.

One point of Professor Ellison's was emphasised by Mr. Cave : It was a waste of time and money to reclaim and reseed land if the subsequent manuring and management were to be the same as before. Unless management and manure were radically improved, the pasture would revert to its former state of low production in three to six years.

Concluding, he mentioned that his observations were based on a short period in a high rainfall area. Whether rotary cultivation would be successful in a low rainfall area in the same way he could not say. But he was convinced that the essential operation was the first rotary cultivation, which much thoroughly shred the old turf. Therefore, he questioned Professor Ellison's first statement that the plough was the implement *par excellence* for grassland improvement. Mr. Cave did not think it was.

PROFESSOR ELLISON thanked the opening speakers and said one thing they had in common was an emphasis on the importance of top soil, and he agreed with that. He also agreed with Mr. Green's points about soil structure and aeration, notably water movement and fertiliser movement. He was very interested in Mr. Cave's experience with the rotary tiller and agreed that burning off could be an important pre-requisite for improving pasture, even in lowland conditions.

MR. A. PHILLIPSON (N.I.A.E.) asked if Professor Ellison considered that existing seed drills were adequate for sowing herbage seeds. Grass seed was small and could be buried too deep, or it could be exposed on the surface so that the seedlings dried out and died. There could also be uneven distribution of clover and grass by some drills because of separation in the hopper caused by vibration. Mechanisms which used a gravity feed and an agitator were liable to give a variation in seed rate at different forward speeds and were also affected by vibration. Was there a case for a specialised grass seed drill, or for a new drill which sowed other seeds as well ?

Mr. Phillipson also asked, considering Professor Ellison's remarks about the high cost of ploughing, if it was not also a high cost method to sod seed if, in addition, chemicals had to be used. One of the advantages claimed for sod seeding—that of continuity of grazing—was lost if chemicals to kill the existing sward were employed ; moreover, sod seeding could never provide ideal seed bed conditions.

PROFESSOR ELLISON said that he was in doubt on the grass seed drill question. As an agronomist, he entirely supported what had been said ; the present drills had many faults. He could mention, in addition, the problem of sowing any seed which had an awn on it, like Italian rye grass. However as a farmer, he was reluctant to advise the farmer to buy yet another machine. Unless it could be an improved general drill, then he did not think in practice there was a very strong case for a specialist drill. While chemicals were expensive at present, there was good reason to hope they would become much cheaper in the not too distant future. " Dalapon " had already been halved in price, and some of the new ones which were still expensive should soon become cheaper.

MR. J. M. CHAMBERS (Warwicks.) stated that, *à propos* of the question of disturbing the soil when turning over the top 2 ins., in some parts of the world where they practised soil conservation from wind and water they tried to leave the crop residue on top of the soil. Consequently, they tilled the soil with a wide, full blade, sometimes with a disc coulter in front to give as little disturbance as possible. Would that type of implement be useful ? He had seen a machine over in this country from South Africa where it had been used in golf course work. It had a wide blade ; it raised up the soil and fertiliser was sprayed in.

PROFESSOR ELLISON said that when he was in Canada he had been interested in the various types of " blader " machine that they had there. He thought that such a tool might be used to control rushes, because their root went deeper than an ordinary grass sward. If rushes were cut off at the roots it might be a way of control—perhaps for thistles and docks as well.

MR. W. H. CASHMORE (N.I.A.E.) declared that Professor Ellison had strengthened his belief that there was an alternative to the plough in renovating grassland. It was unfortunate that the national policy was in favour of ploughing up. This had two bad effects—the first was that the impression was created that there was no alternative, and the second that many of the heavy cultivators that they had had before the last war had disappeared. In Professor Ellison's slides of New Zealand reclamation work the land had been made first of all almost bare, while in this country there was a lot of mat. Heavy cultivators were good at getting rid of mat, and the wetter the conditions the better they worked.

He enquired if Professor Ellison had any experience in the use of flail forage-harvesters for getting rid of poor top grass ?

PROFESSOR ELLISON shared Mr. Cashmore's regret that implements which could play a vital part had disappeared, and hoped that someone would bring them back. With regard to forage-harvesters, he thought Cuthbertson had used a modified rotary flail type of forage-harvester to make a mulch on the surface into which the seeds could be sown under high rainfall conditions.

MR. BURTT (Massey-Ferguson, Ltd.) referred to his experience in New Zealand. Control of a pasture after sod seeding could be provided by electric fences. In New Zealand a machine had been developed which would lift out rush plants individually ; it was attached to the tractor three-point linkage system.

THE PRESIDENT reminded the audience about the importance of paying attention to the soil, which had been brought out strongly in the Paper and in the discussion. Nobody had mentioned the availability of labour, and the President asked what sort of labour would be available. One point that had emerged was the upward trend in the use of chemical ploughing ; if that was going to help, it was a very useful contribution. He thought Mr. Green had opened well, and he could visualise the old gyro tiller coming back in a different form. Mr. Cave, he said, had brought a very strong practical interest into the meeting.

OBITUARY

It is with great regret that we report the death on the 31st March, 1962, of Mr. H. D. Phelps at the age of 73.

Mr. Phelps was an electrical engineer of high repute and well known all over the North of England in his capacity as Agricultural Officer for the North-Eastern Electric Supply Co., which after Nationalisation became the North-Eastern Electricity Board. He retired only a year ago at the age of 72 after having been prominently associated with the rural electrification of the North-East of England since the pioneering days when he was engineer in charge at Malton and Thirsk. In those days each area had its own generating station, and in his own words, quoting from a letter he wrote to a colleague :

> " We designed and built and scrounged our own switchboards—one section being part of the old Neptune Bank Power Station, Wallsend (55 years ago)—and erected the machines, gas producers, pipework, etc., with the help of only one skilled engineer."

Mr. Phelps was one of the founder members of the Northern Branch of the Institution of Agricultural Engineers and one of the original Committee Members. He was Chairman from 1951 to 1953, and from 1956 until virtually the time of his death he held the office of Secretary.

His interest and enthusiasm were of inestimable value in establishing and consolidtaing the Northern Branch. Whenever problems arose in the running of the Branch, as they always do from time to time, Mr. Phelps never failed to find the solution. When there was a danger some years ago of the Branch having to close through lack of accommodation, it was he who brought about the happy arrangement whereby the North-Eastern Electricity Board generously allowed the Branch to use its most comfortable lecture hall at Carliol House. For this and his help in many other directions, the Branch will always owe him a debt of gratitude, and he will be greatly missed by his many friends in agricultural engineering circles.

FARM BUILDINGS AND MECHANISATION

by PETER J. M. ASTON,* M.A., A.R.I.C.S., Q.A.L.A.S., M.I.W.S.

A Paper presented at an Open Meeting on Tuesday, 13th March, at 6.45 p.m., at 6, Queen Square, London, W.C. 1.

SUMMARY

THE Paper examines the different mechanised methods of handling farm materials at the buildings, and considers their significance for building design. Buildings are shown to have the dual function of providing a suitably controlled environment and assisting efficient materials handling. Handling methods are divided into those making use of conveyors and those which depend principally on tractors or vehicles for movement of unit loads, and reference is made to the building requirements associated with each method.

Problems and benefits arising from mechanisation are then examined in relation to grain, potato, cattle and pig buildings. It is predicted that the biggest development of mechanisation in the next few years will occur in the sphere of cattle management.

The Function of Buildings

" Farm production consists of the application of work to materials." This simple definition could equally well be used for any form of industrial production, but farm production has the unusual characteristic that many of its materials are living things in the form of livestock and crops. Whereas in other industries it is the function of buildings to give weather protection to men, machines and materials, and provide a comfortable working environment, buildings on the farm have, in addition, to provide a suitable environment for animals and crops. This is a most important distinction, which makes farm building planning potentially more complex than the planning of other industrial buildings. Whilst never overlooking the importance of ease of working, it is important to remember that in most circumstances " the primary function of buildings is provision of a controlled environment."

Turning next to the work content of farm production, it is apparent that erection of any kind of building must to some degree impede freedom of movement. Expressed in another way, it imposes limitations on the methods which can be used for farm materials handling. The function of buildings planning is thus, firstly, to provide a suitable environment, and secondly, to ensure maximum freedom of movement. In view of the rapid rate of development in handling methods, and in the machines associated with them, it is necessary in the latter case to take account not only of known existing methods, but also of methods which may possibly be developed in the future.

Although it is fair to say that buildings generally restrict movement, there is one important way in which they may assist it—namely, by making use of gravity. It is possible that, in our recent pre-occupation with methods of moving materials horizontally, we have overlooked some of the potential advantages of gravity.

Materials Handling within Buildings

Having thus defined the functions of buildings in general terms, we must next consider the methods of moving materials for which provision has to be made. Men and machines are substitutes for one another in the carrying out of work. Up until recently most of the developments in mechanisation of farm operations have been in field work, and mechanisation at the buildings has been principally concerned with the handling of grain. We have, however, now reached a stage where the emphasis is shifting to mechanisation of work in and around the buildings, and this calls for fresh thinking on the problems of buildings planning. The integration of building design with modern handling methods has now become one of the most urgent requirements for the development of efficient, low cost farm production.

When one starts to consider the mechanised methods of handling farm materials which are currently available, it is all too easy to become confused by the many variations which are found in practice and by the multiplicity of machines associated with them, many of which do the same jobs in slightly different ways. In other words, one may lose sight of the wood for the trees, for details of machinery design can change from year to year with bewildering rapidity. For the buildings planner the essential first step is a definition of basic handling methods and of the principal classes of machines associated with these. The permanent or semi-permanent building structure can then be planned to conform to the requiremenst either of a range of basic methods (flexible or multi-purpose design) or of a single selected method (specialist design). The proportion of removable to fixed building fittings must inevitably be higher in the former case, since a change of basic handling method will almost certainly involve a re-arrangement of interior building layout, and possibly also of external wall openings.

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The following is suggested as a logical classification of basic handling methods :

Handling Method	*Nature of Materials Handled*
1. Continuous movement by means of : 1. Gravity. 2. Various types of conveyor : 1. Pneumatic. 2. Auger. 3. Chain and flight. 4. Bucket. 5. Moving belt. 6. Jog trough.	Free flowing materials out of bulk storage.
2. Intermittent movement by means of : 1. Gravity. 2. Tractor plus front and/or rear loader. 3. Fork lift truck. 4. Tractor plus trailer. 5. Lorry or tanker. 6. Certain types of conveyor.	Free flowing or non-free flowing materials in unit loads. 1. Units secured by wire or string—*i.e.*, bales. 2. Units held in containers : 1. Sacks or bags. 2. Boxes or bins (open topped). 3. Tanks (totally enclosed).

A most important point to note about the above classification in the present context is the almost invariable use of a tractor or vehicle at some stage in the handling of unit loads. Since continuous movement by conveyor from field or outside point of supply to the farm buildings is almost certain to be ruled out on grounds of distance, this means that every farm material which passes through buildings must arrive by tractor or by some form of vehicle. If the material can be moved to its final destination by means of conveyor, there may be no need for the tractor or vehicle to enter the building, and in this event the building may be designed specifically for a handling system based on continuous movement of materials by means of conveyors. Many poultry and pig buildings are designed on this principle.

If, on the other hand, delivery of the material to its final destination within the building is to be direct from a tractor attachment or a vehicle (including in this context a fork lift truck), then adequate manoeuvring room, both horizontal and vertical, must be provided within the building. The following are some examples of requirements under this head :

Material	*Handling Method*	*Special Space Requirement*
Fertiliser.	Delivery by tipping lorry for storage in bulk.	20 ft. headroom ; manoeuvring space for lorry.
Potatoes.	1. Transport in stillages. Storage in bulk.	12–15 ft. headroom ; manoeuvring space for tractor and front loader.
	2. Transport and storage in stillages.	15 ft. minimum headroom ; manoeuvring space for tractor, front loader and rear lift, or for fork lift truck.
Grain or Concentrate Feed.	1. Tipping trailer.	13 ft. headroom in tipping position; drive-through space for tractor and trailer.
	2. Road tanker.	15 ft. headroom ; drive-through space for tanker.
Chopped Forage.	Self-unloading forage box.	12 ft. headroom ; drive-through space for tractor and forage box.
Yard Manure.	Tractor front loader into manure distributor.	8 ft. minimum headroom ; manoeuvring space for tractor, plus front loader and distributor.

Where, on the other hand, movement of materials can be by means of conveyors, space requirements for movement are very small. In this case, building dimensions will be governed much more by crop storage and livestock accommodation requirements. Modern mechanised handling methods mostly involve delivery of free flowing materials at the buildings in large unit loads, and these materials are then conveniently stored in upright rectangular or circular silos. The higher these silos, within reason, the lower should be the overall unit cost of storage. This will be so particularly in the case of forage crops, since extra height means greater compaction and a larger volume of material over which to spread the cost of an unloader.

Provision for Storage

Storage for materials which are to be consumed on the farm may be provided within the building in which they are ultimately to be consumed, or in a separate building or silo. If delivery to consumption point is to be by gravity, there are obvious advantages in having everything under one roof (for example, concentrates from a loft into a parlour or baled straw from barn into a cattle yard). On the other hand, if movement is to be by conveyor or by tractor and any form of trailer, then the storage building may more conveniently be detached. In terms of cattle enterprises, this is the American pattern of tower silos linked to the yards by mechanical conveyors, in contrast to the more compact type of self-feed silage layout, with straw stacked above the silage alongside the yards, which has recently become popular in this country.

There is one other aspect which should be considered before leaving the subject of storage—namely, covered accommodation for machines themselves. As the output capacity of machines increases, so does their size, and space allowances for buildings which may house the larger farm machines should be especially liberal. For example, the modern large combine harvester requires door openings 16 ft. wide by 13 ft. high, a floor storage area in the region of 400 sq. ft. and adequate working space for the purpose of farm maintenance. It is not impossible that present dimensions will be exceeded in the future.

Grain Buildings

Introduction of the combine harvester set off a chain reaction of drying and storage requirements, normally involving a capital expenditure of between £15 and £25 per ton stored for provision of the necessary buildings and equipment. If one classifies a silo as a building, and in most cases it is probably reasonable to do so, then many grain storage installations consist in fact of buildings within a building, the latter serving mostly as weather protection, but adding considerably to the overall cost.

One important question in relation to grain building is thus : " Is it necessary to provide building cover for silos ? " If the answer given is no, this simplifies considerably the job of the buildings planner, whose first (but often forgotten) question should always be : Is this building really necessary ? There is, of course, no simple answer in this instance, since so much depends on the drying method adopted, the size of unit and other factors, but the possibility of building simplification should at least be considered.

One of the disadvantages of conventional grain storage buildings is the locking up of building space, which represents fixed capital, for 12 months of every year for a storage requirement which is normally limited to a period of four to eight months. Sack storage overcomes this problem, but it is doubtful whether the logic of mechanisation will permit for long the continued use of sacks in any but the smallest farm units, and even here they may be forced out of the picture by increasing provision of grain storage buildings on a co-operative basis. In order to avoid the locking up of building space, one therefore appears at present to be left with three alternatives—to construct a rectangular building which is in effect a large grain silo, with appropriately strong walls for grain retention, but which on being cleared of grain can be put to other uses ; to store loose on the floor to a maximum depth of about 8 ft. ; or to store in stillages.

If a rectangular building of the type referred to can be designed with quickly erected and demountable panels for both external walls and internal partitions at a price competitive with that of other forms of storage, this would appear to offer many advantages. At least one design of building for which these characteristics are claimed will shortly be obtainable in this country, but more practical information is needed before a fair assessment can be made of its merits.

Loose storage appears to run against the trend of providing specialist buildings and equipment for specialist purposes. In concept, it is comparable to self-feed silage, having similar advantages of low capital cost and flexibility of building layout. Perhaps it can fairly be regarded as a half-way stage, using existing traditional buildings (for example, cowsheds which have become redundant as a result of a change to yard and parlour), to the specialist designed but general-purpose type of building referred to in the preceding paragraph.

Storage of corn in large stillages has been spoken of as a practical method, but as yet there is no on-the-farm guidance to support this idea. It has been claimed that this form of storage would be cheaper than bins, but unless a drier can be eliminated by means of some form of in-stillage drying, the disadvantages might well outweigh the benefits if large tonnages are to be handled. Possibly the method might find a place as emergency reserve storage in years of heavy yield or when quantities to be stored are above average for any reason. If one-ton capacity stillages were used for handling from field to buildings, as well as within the buildings, the method could be either as with potatoes, for the combine to discharge direct into the boxes on a trailer pulled by a tractor running alongside the combine, or else for the discharge to be at intervals from the combine tank into boxes on a stationary trailer. Specialist lifting equipment would be needed for handling at the buildings, but this would be available if potatoes were also handled in this manner. For 10 cwt. stillages only slight modifications to standard tractor equipment would be necessary. This method of handling, if practicable for grain on any scale, would be of considerable interest to the building planner because of the simplicity of its building requirement.

Reverting to circular silos, it might be possible in certain circumstances, now that forage crops can (by means of short chopping) be made into free flowing materials and mechanically unloaded from circular silos, to use certain silos for grain storage in winter and forage crop storage in summer, other silos being used for surplus spring grass stored for winter use. This would fit in with a system of all-the-year-round housing and conserved forage feeding of cattle, which may become popular as management methods become more intensive. This idea leads naturally on to the possibility of storing grain for use on the farm at a high moisture content (normally 25–30%) in air-tight silos. This cuts out the cost of drying, with all its consequential handling requirements, and also provides a more digestible and nutritious food for cattle, if crushed, than dried grain. Such silos do not need a building cover. Experiments by the Rowett Research Institute have shown that barley, when fed in large quantities to beef cattle, must be at least 16% moisture content to be digestible, and grain dried and stored at a lower moisture content has consequently to be moistened before feeding. High moisture storage seems to have interesting possibilities.

Buildings for Potatoes

Mechanised handling of potatoes has taken a definite swing recently in the direction of stillages, initially of 5 cwt., then 7 – 8 cwt., then 10 cwt., and now even 20 cwt. capacity, but there have been few instances as yet of storage as opposed to transport by this means. This is probably due mainly to the relatively high cost of the large number of stillages needed (between £3 and £5 per stillage if made up on the farm), and now that the plunge has been taken by a few farmers, others may well follow. Building requirements for this form of storage need further study, with particular reference to insulation, ventilation and light exclusion. Of these factors, insulation may prove to be the most awkward in the context of a general-purpose building.

More and more large units, in many cases probably on a co-operative basis, are likely to combine storage with prepacking, and here there will be carefully integrated systems of mechanised handling, with storage either in bulk or in stillages. For such units it should be possible to design the buildings specifically for this specialist purpose, but for the general run of farms the building should be suitable for other uses.

Buildings for Cattle

It is in the sphere of buildings for cattle that mechanisation is likely to have the biggest impact within the next few years. Since cattle housing and associated forage and litter storage space account for the greater part of the buildings on most livestock and many mixed farms, and since complex crop and stock husbandry and materials handling factors are involved, there is likely to be widespread argument and indeed confusion over the true benefit of mechanisation in this sphere.

In addition to free flowing concentrate foods, we are here concerned with handling three classes of bulky materials, none of which in the past has normally been free flowing ; namely, conserved forage (principally grass), litter (almost invariably straw) and manure. Grass for silage has normally been cut by forage harvesters and placed into bunker silos by a variety of more or less complicated methods ; grass for hay has been mown, turned, baled and placed in barns by an even wider variety of methods ; straw has been handled similarly to hay ; and manure has been handled by various means into distributors for spreading on the land, with any liquid portion being led *via* elaborate drainage systems to some (often inadequate) means of disposal. For all this a wide range of relatively expensive machines has been necessary, including forage harvesters, forage boxes, balers, elevators, front end loaders and manure distributors, plus a liberal allowance of man hours. Self feeding of silage has removed the handling problem associated with the distribution to stock of that particularly awkward material, but in many instances has created a slurry and a food wastage problem in return.

This confused and illogical pattern of handling methods for getting the materials into the buildings has not directly affected the buildings planner, who has by and large been concerned merely to provide suitable storage space and means of distribution after they have arrived there. This he has done in many cases, under the pressure of recent years to reduce the labour content of cattle management, in a reasonably logical manner, abandoning the cowshed as beyond reasonable integration and adapting American ideas on loose housing in a sensible way to meet the special requirements of this country. In short, there has emerged a pattern of cattle yarded in a lean-to building alongside a high barn containing baled straw and hay on top of about 6 ft. settled depth of silage. The cows have direct access to the silage face for self-feeding, the straw is thrown direct down into the yards and hay into racks adjoining ; the slurry is scraped to a distributor or to a temporary holding pit, and all concentrate foods for dairy cows are fed in the milking parlour. The buildings, except for the parlour and dairy, are of general-purpose design. This building pattern, in the context of the management methods for which it was designed, makes sense.

Now, however, there are emerging new pressures. Shortage and high cost of straw in the grassland areas have directed attention to alternatives to straw for bedding, and slatted floors have emerged as one possible solution. Low-level slats can be linked with a mechanised system of water-borne disposal *via* pipe-line on to the land. The capital cost of the necessary slats, storage tanks, pumps and distribution pipe-lines is high, but it can, if properly planned, remove most of the labour element from manure disposal and combine the advantages of organic manuring with those of irrigation. Further impetus may be given to development along these lines by recent legislation which is certain to lead to strong action to prevent the pollution of watercourses by farm drainage. Disposal by pipe-line on the land is one solution to this awkward problem.

The pattern of lower prices for farm products on the one hand, and increased production costs, especially labour costs, on the other, which is likely to characterise the years ahead, will give further impetus to more streamlined, low cost, scientifically planned production methods. With present methods, output from grass is nowhere near its potential, and production costs for most farms, if honestly worked out, are high. Developments in mechanised methods of forage harvesting and handling, in particular the increasing use of field choppers in combination with self-unloading trailers, blowers, tower silos, mechanical silo unloaders and in some cases mechanical conveyors for feed distribution, are helping to force the pace of movement towards more highly specialised but scientifically planned, high output, low unit cost production. The tower silo itself, which we may class as a building, is a vital link in this handling chain, enabling rational mechanisation of the whole process from field to feeding, reduced storage losses and a better quality forage product.

Where this mechanised pattern is adopted, and straw continues to be used for litter, handling methods for the straw must surely become integrated with the forage handling system. This means field chopping, transport in self-unloading trailers and blowing into building containers, pending removal as required for bedding. It is the distribution method to the yards or cowsheds which now requires further attention. Present evidence indicates that less chopped straw is needed for bedding than long straw.

For the building planner, the implication of these developments in mechanised handling methods are considerable. He cannot overlook the advantages of simplicity and low requirement of fresh capital of self or easy feed bunker silage in conjunction with conventional handling methods, but on the other hand he must be prepared for a full swing of the pendulum on an ever-increasing number of farms to the new methods. He must, therefore, carefully consider whether any new buildings or adaptations should be designed to accommodate a system of food distribution by mechanical conveyors, or alternatively by side delivery self-unloading trailers, the layout requirements for the two methods being substantially different. He should also consider provision of bins for chopped straw and methods for distributing this. Possibly he should consider storage in a loft above the bedded area. Development of short chopping and blowing into buildings may turn the wheel full circle back to two-storey construction in certain instances.

These developments in mechanised handling methods are likely also to stimulate renewed examination of the merits of cowsheds, and even of buildings for the tying up of fattening cattle. Cowshed design has been stagnant ever since the last war, but the time is now ripe for re-examination of the subject. American trends towards mechanised conveyor feeding from tower silos, with cows facing inwards instead of outwards for economy of conveyor provision, distribution of chopped straw litter by self-unloading trailers, removal of manure by scraper (or by a water-borne system from a channel beneath slats), and for the larger herds four instead of two ranks of cows, may well set the pattern for developments of cowshed design in this country. In these circumstances, cowsheds could well regain much of their lost popularity, particularly where straw is in short supply.

Buildings for Pigs

There is time for no more than passing reference to this class of building. The trend is at present clearly towards controlled environment, totally-enclosed houses, but with a tendency for smaller units to enable resting of buildings at intervals as a guard against disease build-up. Fully mechanised feeding has been rather slow in development, but the pace may quicken. Slatted floors have proved successful and popular for the dunging area, sometimes accompanied by water-borne disposal of manure.

Up to now little attention has been given to the potential advantages of circular construction for piggeries. With this construction, mechanised feeding can be easily arranged by means of a centrally-pivoted arm ; manure can be collected in a central pit beneath slats for mechanised disposal ; uniform ventilation is made easier, and the proportion of wall to floor area is considerably reduced. Bearing in mind these advantages and the trend to smaller units on health grounds, circular buildings may become more popular.

Conclusion

We are likely to witness major changes in agricultural production methods in the next 5 to 10 years, and mechanisation of handling operations in and around the buildings will almost certainly be prominent amongst these. We can no longer accept the methods which may be found on a farm today as the established pattern for the future, and it is the future as much as the present for which our buildings must be planned. Appreciation of the significance of present trends in husbandry practice and mechanisation, as well as in marketing requirements, is essential if buildings are to be planned adequately for tomorrow's needs.

DISCUSSION

MR. R. G. MORTIMER (Harper Adams Agricultural College) began by expressing his thanks for being asked along. He congratulated Mr. Aston and the Farm Buildings Association for their efforts, but in spite of this, however, he felt that one thing that was needed was a farm buildings research institute, because there was a lack of information in the subject. Far more results would come forward, there would be more facts and figures and more " meat." Engineers had much information on the performance and output of machinery at the N.I.A.E. and similar bodies, but little information about farm buildings. This did not detract from the work of Mr. Aston and his colleagues.

Mr. Mortimer had found it difficult to disagree with anything Mr. Aston had said. As the audience knew, they were interested in that field at Harper Adams. However, Mr. Mortimer declared that he was going to leave circular piggeries alone, and was going to consider forage and material handling.

One point Mr. Aston had tended to leave out was the capital involved. Many of the developments he had talked about were going to involve the farmer in spending a lot of capital, and Mr. Mortimer adopted a slightly different attitude to this problem than the author of the Paper. The latter had talked about the way the material was handled and the saving of labour, but a more exact —and more profitable—way of looking at it was in relation to the output of the farm. Buildings of the future should be considered in terms of higher and better quality output of the farm.

This applied not only to cereals, but also to potatoes and forage. Mr. Aston had mentioned the advantages of storing potatoes in stillages. Mr. Mortimer thought that more people were storing in stillages not because that was an easy way to handle potatoes, but because there was less damage to them. Many farmers were going over to pre-packaging methods, and the problem that most of them came up against was the high wastage due to mechanical damage in the potatoes coming forward. Their " break even " percentage was 80 per cent., but in so many cases they were down to 50 or 60 per cent. acceptibility. Storage in stillages might therefore become popular because of better quality.

Increasing the quality of output applied increasingly to forage harvesting. It was possible to look at the latest storage and feeding methods in terms of saving labour. The first unit in this country had been at Harper Adams, and they were concerned with it there not so much because one could feed 40 bullocks in 10 minutes and that those bullocks were putting on 3½ lb. to 4 lb. a day. The important result of using tower silos was a better quality product, so that the output of land was increased by one-quarter to one-third, and more stock could be carried. It was necessary to look at the output of buildings in the future, and that was why more factual information was needed.

One point that Mr. Aston had tended to ignore was sludge handling. Mr. Mortimer agreed that developments in the cattle industry would be important, but sludge and litter handling would also be important.

He did not think that slatted floors and organic irrigation were necessarily the answer. They knew what had happened to organic irrigation in many cases that winter—the installations had frozen up.

It was necessary, he continued, to have batch feeding methods. A limited feeding area would reduce capital cost of the equipment, so that instead of having to pay for augers and belts running for 200 ft. or more, it would be possible just to have a short length and bring the cattle in in batches.

Summing up his remarks, he repeated that the main criticism of the Paper was that there was a shortage of data—not enough meat for them to go ahead and plan. But this was not Mr. Aston's fault ; rather was it caused by the set-up in this country.

MR. T. DEWES (Machinery Advisory Officer, N.A.A.S.) remarked that they had heard someone in building design say that in future it would be necessary to consider the machinery before the buildings. Mr. Dewes asked who would design these buildings ; would it be engineers or architects in the future ? He thought it essential that the engineer had a say.

Mr. Aston had dealt with grain handling and other subjects, but one very important point missed out was the size of farms in this country. Many were small and could not put up some of the equipment mentioned. Perhaps syndicate farming might be an answer, and possibly dairy farms could co-operate to put up the installations in question. However, farming policy on any one farm had got to be considered individually, and one could not overcome this.

Mr. Dewes asked if Mr. Aston had had any experience with electric vibrator equipment, for assisting gravity feeds, and in conveying free-flowing materials.

Mr. Dewes then referred to the view that loose storage was something that could be put into a general purpose building. But a building was general purpose no longer if permanent walls were erected. He was not sure that a permanent wall was necessary and thought that the building research people could devise a temporary one. On grain at high moisture content, he believed that if grain was brought in at 25 to 30 per cent. moisture content it would be uncombinable, and asked if it would flow and go through a crusher.

Insulation of buildings for potato storage had been mentioned by Mr. Aston, but Mr. Dewes did not think that was such a problem as handling. In East Anglia, potatoes stored in stillages had suffered very little frost damage.

What appealed to him in tower silos was self-feeding. In the U.S.A. they used a mechanical conveyor in the form of a trough round the tower silo, and self-fed the silage. He mentioned the possibility of a return to cow cubicles where the straw supplies were limited.

MR. W. J. AGGAS (Sussex) agreed with Messrs. Aston, Dewes and Mortimer that in the design of farm buildings there must be co-operation between the Ministry, all the various engineers in the country, and people like himself, who spent their time messing about on farms with buildings. He was all in favour of moving stuff by gravity, but said that this would change completely the present-day design of farm buildings. They would have to be higher and the steelwork or concrete increased in size if they wanted a 30 ft. span building to house milking cows or beef cattle with the necessary hay and straw above. Storing materials in such a loft and with such a span would require considerably more strength in the stanchions and cross-members, and whether this was economic remained to be seen.

He thought that the human factor must be considered when contemplating the feeding or littering animals by push-button methods. Most farm workers were technically-minded, but some were not ; equipment must be robust and foolproof.

Referring to grain storage, Mr. Aggas said that he did not see why bins should necessarily be placed inside a main building, although the wet grain pit, pre-cleaner, pre-drying bins, drier and grader and sacking-off space had to be housed. The bins could be provided with sound, gale-proof roofs, and the sides of the bins could be cladded with asbestos for insulation and weather protection. They should be erected on a raised floor, and the low-level duct should be able to be drained.

He had no personal experience of slatted floors, but bearing in mind the quantity of water probably required to keep the material as sludge so that it would flow, it worked out that in a building 60 × 30 ft., with a 2 ft. pit underneath, the cost of washing and flushing out could be £1 to £2 a day. Existing water supplies in the country were not always sufficient to provide this volume and pressure. One farmer he had met had gone back to using his own water supply after he had had his first account for water of £7 to £8 a week.

MR. ASTON, in replying to points that had been raised, said that the most important one from Mr. Mortimer had drawn attention to the lack of data, and Mr. Aston agreed with him absolutely. It was, for example, ridiculous that silo manufacturers referred to silo capacity in terms of so many tons of silage. This meant nothing and assumed that silage was always the same, whereas it could be as different from another batch as chalk and cheese. It seemed to Mr. Aston one of the basic things, for silage with 50 per cent. dry matter was quite different from that with 20 per cent. and handled differently.

Batch feeding offered possibilities for cutting costs, and there was no reason why it should not be done. He agreed that the small farmer would have to co-operate much more in order to survive.

On some farms with the high-capacity combines driers were not able to cope with the rate of grain inflow. Electric vibrators had, he considered, quite a lot of scope, but he had no experience of them. He had referred to the general-purpose building, he claimed, as having easily demountable internal *and external* walls, and he agreed that unless walls were demountable it was not a general-purpose building.

He thought that more people would go back to cow sheds—fashions came and went. There were two basic systems of housing cows—the loose and the restricted (*i.e.*, cowshed). There had been much interest in loose housing recently and it only took a number of years of one system to draw attention to the disadvantages of it, and thus to the advantages of the other. Interest was already swinging back to cowsheds, partly because of the mechanisation problem, and in America more farmers were building cowsheds than loose housing layouts.

MR. EDWARD DAY (Kent) asked what the difference in density was between baled hay and chopped straw; were they letting themselves in for larger buildings for the same quantity of straw ?

MR. ASTON replied that nobody knew—it was one of the ridiculous things. Some farmers had made experiments and his own information was that the chopped material did not occupy much more space. The figures for straw were being gone into.

MR. MORTIMER rose to comment that at his college they had been carrying out trials that winter on chopped straw for bedding spaces. They had not found a saving of space, but had found that the total consumption was reduced. The chopper could be used as a stationary machine, and if on a Saturday morning they had got some odd bales they would chop it in that way. It was better, however, to chop it in the field, he added.

MR. DAY asked how the chopped straw was handled.

MR. MORTIMER told him that it was handled by large bucket on a fore-end loader. The bucket was used for their silage system as well as for the straw.

MR. A. ROSEN (West Sussex) described his experience with high-moisture content grain. He had been worried when he was told their 14 per cent. must be raised to 18 per cent. However, he had, on advice, poured water on it, and was doing this with great success on all the grain they were selling.

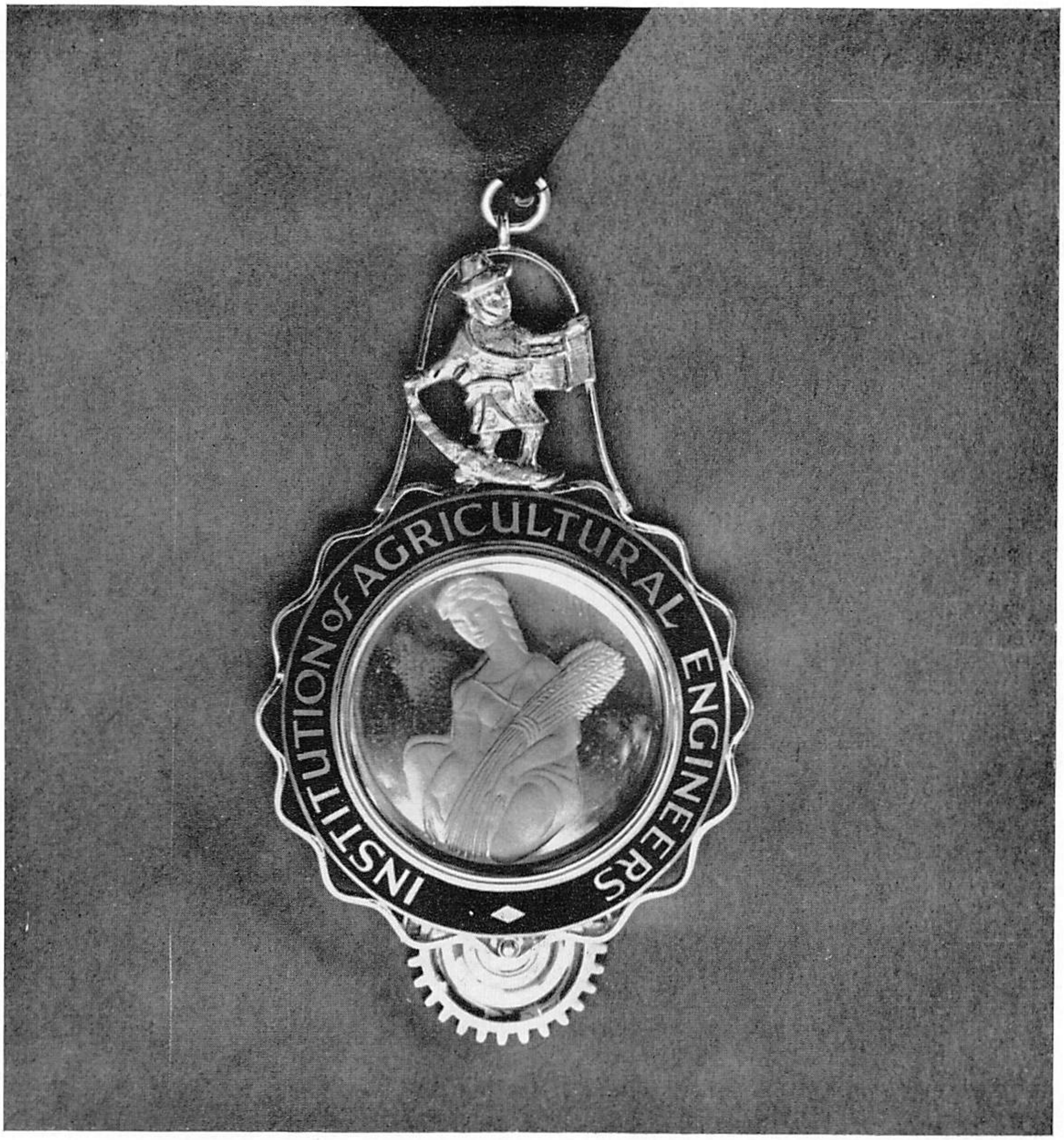
THE PRESIDENT thanked all the openers of the discussion. He was sorry that Mr. Mortimer had no time to say anything about pigs. Points he singled out were that the questions of co-operation and of capital investment should be borne in mind as seen through the eyes of the farmer. He thought they could look to Mr. Aston to try and get the co-operation between those who should be concerned with farm buildings. It was up to someone, and perhaps through his Association he could start the ball rolling. The President was glad to hear that a profit could be made out of selling water !

Mr. Aston was reminded about one point of Mr. Dewes'—the place of the engineer in planning buildings. He said that this was about the only country where buildings on farms were highly developed and where agricultural engineers were not directly concerned with their planning. The American Society of Agricultural Engineers had a buildings section, but in this country, for reasons associated historically with the system of land tenure, the land agent rather than the architect had taken the problem on his shoulders. The engineer now had an increasingly important part to play.

ANNUAL CONFERENCE AND ANNUAL GENERAL MEETING, 1st MAY, 1962

Some 150 members were present at the Second Annual Conference held at the Royal Society of Arts on May 1st. The Papers and ensuing discussion appear on pages 63 to 86. Immediately before the commencement of the Conference the Founder-President, Lt.-Col. Philip Johnson, formally presented to the President, Mr. Nolan, the Presidential Badge of Office, a gift to the Institution from Shell-Mex and B.P., Ltd. A photograph of the Badge appears on page 62.

Owing to the pressure of space in this issue, the report of the Annual General Meeting has been held over for publication in the July issue.



THE PRESIDENTIAL BADGE OF OFFICE

This President's Badge of Office has been presented to the Institution by Shell-Mex and B.P., Ltd., to mark the end of a three-year term as President by Mr. W. J. Nolan.

At a luncheon on April 10th, 1962, the badge was handed over by Mr. John Davies, Vice-Chairman and Managing Director of the Company, who said the presentation was made with " humility, affection and regard " for the work of the Institution. It was received on behalf of the Institution by the Founder-President, Lt.-Col. Philip Johnson.

The badge was designed by Miss Helen Monro, Head of the Department of Glass Design, Edinburgh College of Art. The central figure, engraved on crystal, is Ceres, goddess of the fruits of the earth. The crystal is contained in a silver mount. Above it is a mediæval sower, derived from a figure in the Fourteenth Century Luttrell Psalter in the British Museum, and below is a gear wheel symbolising the application of machine power in Agriculture.

Papers presented at the Institution Conference, 1st May, 1962

THE COST OF MECHANISATION ON ARABLE FARMS

by D. B. WALLACE,* M.A.

Introduction

WITH home agriculture facing an increasingly competitive future, whether we join the Common Market or not, the thoughts of everyone connected with the industry are turning more and more towards the problems of costs rather than output. Indeed, in the last year or so, farmers have even begun to look seriously outside the traditional sector of costs —those directly involved with the farm and its operations, —and attempts are being made to attract some of the margins which normally go to those who service the industry, whether it be suppliers or buyers, by virtue of co-operatives, trading groups, syndicates and the like.

Under this new approach, machinery costs must obviously come up for ever-increasing attention, accounting as they do for perhaps a quarter of the total costs of a cropping farm. Up to now, machinery costs of the whole farm have tended to be ignored, because it is so hard to do much about them in the short run, while much attention has been given to costing individual processes or machines. But while this data has provided useful background information, it has been extremely difficult to make use of it when trying to remedy a farm's shortcomings.

In this Paper it is proposed to approach the problem of how much machinery a farmer can afford from a rather different angle than the fairly usual one of finding out what current average costs *are* and using those as a guide. Instead, the approach will be from the standpoint of someone who is able to make a fresh start. What machinery should he have and what will the costs be? A question of "what should be" rather than "what is." To this end, the Paper is divided into four parts. First, a consideration of what machinery is *for* —what it is that a farmer is obtaining, in an economic sense, when he buys one particular machine rather than another. Then the pattern of machinery likely to evolve on a typical arable farm is considered, together with an estimate of its capital cost. This can be termed the cost of *procurement*. Thirdly, the costs of *operation* are discussed. These last are the costs which appear in so many economic publications as machinery or power costs per acre. In conclusion, an attempt has been made to answer the questions as to whether farmers on the whole have too much machinery and what they should do about it.

The Purpose of Machinery

What does a farmer buy when he purchases machinery? In the concrete sense, he gets a mechanism, usually of metal, for doing some sort of job. But in the abstract sense, he buys *capacities*—capacities to grow a given volume of crops or keep a given number of livestock. This may seem a hopelessly theoretical way of looking at the matter, but in fact it is how the farmer really goes about it, if only sub-consciously. To take an example: A farmer is shown a certain type of combine. What he wants is a machine that will allow him to carry out a particular task of a given size—not just to cut corn, but to cut a particular *acreage* of corn in a stated period. This model may cut 300 acres in a normal season. Our farmer may only have 200 acres to harvest, so he may consider a smaller and cheaper model. On the other hand, his district may have a fairly short harvest season, well below the average. In such circumstances, if he wants to grow corn he may be well advised to have this model with a high throughput to be sure of his harvest. So what he is shopping for is the *capacity* to take his harvest in a short period—200 acres in, say, 12 cutting days, whereas another man in a more favoured area could rely on 20 days for the same acreage.

This is an over-simplified example, but it serves to illustrate the first economic characteristic about machinery. It is in terms of the capacity it gives the farmer to produce crops and stock that machinery should be judged in the first place.

The second characteristic of machinery is that it does not stand by itself. The labour force on an arable farm is primarily employed to operate *with* machinery, so that the two must be considered together. (In livestock production, buildings and their layout may take the place of machinery in the conventional meaning of that term. The principles involved are just the same, but this Paper is confined to arable farming.) This again may look like a truism, but many people forget it when assessing the labour force that a particular farm should have. They total up the crops and stock to calculate the man-days, for instance, but leave out the type of equipment involved. As a result, they are sometimes misled as to the labour force that should be kept on any particular farm.

In fact, where hand labour is available, it is often no more expensive in agriculture than machines. Combining is not noticeably cheaper per acre than the older methods of harvesting, especially when grain storage and straw disposal are taken into account. Yet farmers persist in changing over, so that a threshing drum is becoming a rare sight, in the Eastern Counties at least. The true situation is that the combine not only allows far fewer men to harvest a crop, but also to harvest a greater acreage in less time, and it is this combination of

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fewer men and greater security in bad weather that has tipped the balance decisively in favour of the combine. As labour has become more difficult to find, so attention has naturally been given to equipment which made do with less men, but the substitution of capital for labour has not necessarily lowered total costs in that particular operation.

It is a characteristic of agriculture that while regular labour is employed constantly throughout the year, most machines are used for only a few days each season. The prime movers are at work fairly constantly—indeed, on the more streamlined farms they are directly comparable with the regular labour, being at work each day. But other equipment, such as combines, drills, harvesters and the like, may work less than four weeks each year, yet their annual costs may equal those of the prime movers and regular labour together. This means that unwise or unnecessary investment in high cost but little-used machinery will result in, perhaps, adding 50% or more to annual machinery costs of a farm.

It is a fact that much so-called mechanisation of arable farms has been very badly planned. New equipment has been introduced piece-meal, to mechanise specific tasks, without any thought being given to the overall effect. In one corn-growing district the numbers of men per 100 acres had *risen* slightly by 1954 compared with 20 years previously, despite the introduction of tractor and combine in place of horse and binder. The reason is not far to seek. Just because one operation is mechanised, requiring less labour, there will be no reduction in the regular staff if some other vital operation at another time of the year requires the original number. It is these " peak " periods that dictate the number of men that a farming pattern requires. To produce an integrated combination of men and machines, it is necessary to identify these peaks and seek to reduce the demand at those times, either by changing the techniques involved —which may mean mechanisation or different growing methods—or by altering the cropping pattern. There is little point in trying to save labour by mechanising an operation occurring in a period when the demand for labour is below that of the peak, for the total number of men needed on the farm will not be reduced thereby. The farmer may, in fact, carry out such a change for other reasons—greater security against weather, or because it allows him to grow more of a valuable crop. But neither of these reasons, valid though they are, have anything to do with the reduction of labour.

So we come to the conclusion of this part of the discussion. The farmer should look on his farm as consisting of a group of common services—common costs is another name—comprising his land, regular staff and machinery. These can be deployed in different ways, growing different patterns of crops and stock. It is the object of farm planning to produce the best combination of enterprises for any given set of common resources to give the highest profit. Machinery plays its part in this exercise by giving the farmer certain capacities—for instance, the ability to grow up to 300 acres of cereals, up to 40 acres of sugar beet, up to 30 acres of potatoes, keep up to 60 cows, and so on. He must decide how to combine the enterprises within these limits. If he thinks a change in capacity will improve his profits, then he must study how best he can achieve that change—a different type of machine, a contractor's help, a second machine, and so on.

Therefore, if the original question, how much machinery can a farmer afford, is to be answered for any particular cropping pattern, one must work in the opposite direction to the farm planner. Instead of taking the common costs as given and working out the pattern of enterprises, one can take the cropping pattern as more or less given and map out the lowest cost combination of men and machines that will do the work. In practice, it may be necessary to accept changes in the cropping pattern to make the best use of equipment, but this approach does give farmers who have already established their farms a target towards which to work, taking, perhaps, several years over the process.

Procuring the Equipment

The first practical step is to go through the cropping systematically and consider the reasonable *minimum* of labour and equipment necessary to perform each task in the period. A farmer already operating a farm can rely upon his own or neighbour's experience for some of this. But with rapid changes being made in equipment and working methods, consultation with agricultural engineers and advisers is almost essential, and also, perhaps, reference to published results. This type of planning, the synthesising of a farm machinery pattern, is relatively new. Reference may be made to Sturrock in 1955[1] for an early example. Practical capacities for different types of equipment and crops can also be found there and in Culpin.[2]

After working through the farming year to discover the minimum apparently required, look at the peak labour demand. If it is found that three men can manage, except at one period in the year, when a fourth is required, then the farmer may try to reduce this peak demand to three by altering his equipment, employing a contractor or by altering the cropping. But if the cost of such changes is going to be greater than the saving of one man's wages, it is clearly not worth doing. Once this is established, it would be worth looking at the other periods of the year and deciding whether rather less expenditure on machinery could not be made if four men were to be used at those periods as well. It is worth noting that the saving of a man's wages would justify machinery expenditure of about £2,500. Conversely, if the man cannot be saved at one period, and so must be employed through the year, could not some saving in machinery be made at the other times by using the fourth man rather than three.

The result of such calculations will be to provide a physical inventory of labour and equipment required to run the farm. It will then be necessary to price this out to discover the capital cost of machinery, which will provide the target figure the farmer is seeking.

[1] F. G. Sturrock, *Farm Mechanization*, Sept.–Dec., 1955.
[2] C. Culpin, " Farm Mechanisation Management."

A short example may serve to make this clearer (the figures used are only for illustration) :

Farm size—240 acres arable, cropped as follows :

Year 1—Sugar Beet, 40 acres.
Potatoes, 20 acres.
Year 2—Wheat, 40 acres.
Barley, 20 acres.
Year 3—Barley, 60 acres.
Year 4—Barley, 60 acres.

Starting with winter, there are 200 acres of spring crops for which seed-beds must be prepared, and at a later stage another 40 acres for wheat. Making use of the figures in Culpin, these crops will require two ploughs, and hence two men and two tractors, but, working at a minimum, only one of each of the normal cultivation equipment. Then follows corn drilling—a combine drill —root drilling, and so on. The detailed requirements have been set out in Table I.

Table I

LABOUR AND MACHINERY REQUIREMENTS FOR ARABLE OPERATIONS

Tasks	*Men*	*Equipment*	*New Cost**
Winter :			£
Ploughing and seed bed, 200 acres spring crops ..	2	2 ploughs, 1 cultivator, 1 disc, 1 set rolls, 2 harrows	680
Spring :			
Drilling 140 acres barley ..	2	1 combine drill ..	200
Drilling 40 acres sugar beet..	2	1 precision drill ..	200
Planting 20 acres potatoes ..	3	1 mounted planter ..	150
Inter-row work, 60 acres ..	2	1 tractor hoe, 1 set ridgers, 1 thinner ..	450
Crop spraying 240 acres ..	1	1 sprayer	100
Summer :			
Cereal harvest, 80 acres ..	3	10 ft. combine ..	1,500
Baling straw (? straw might be ploughed in)	3	1 baler and sledge ..	(? 450)
Autumn :			
Potato harvest	3	1 spinner, 1 riddler ..	300
Wheat ploughing and seed-bed..	1	equipment included above	–
Wheat drilling	2	equipment included above	–
Sugar beet harvest	3	1 harvester	400
To draw this machinery at least two tractors will be required, though many may prefer a third cheap one as a standby. In addition, at least one tipping trailer is required. Again many would prefer two. Then add			1,200
		Total ..	£5,180

* Illustration only.

This is just under £22 per acre if all were bought *new*. Before considering the question of secondhand equipment the number of men must be cleared up. At first sight, it looks as though three men are the maximum required. But in the autumn, potato and beet harvest are likely to run into one another, and with 60 acres of roots involved, it might be difficult to get the wheat in as well. The farmer faces three choices—to keep a fourth man throughout the year, to use a contractor to prepare 40 acres for wheat (the drilling would only take two or three days), or to grow only spring corn. If the farmer did not wish to work manually most of the year, he might consider being the fourth man himself. If, however, he were proposing to be more or less full time at manual work, he would have only two other paid men, and would consider one of the other alternatives, depending upon the relative returns of the various crops and contractors' charges. In our case he decides on two men and himself, and the use of a contractor. Now he has fixed on this number, he may look at one or two of the other periods to see whether it is necessary to have so much machinery. Sugar beet singling—now he has three men (including himself) who could do, perhaps, half the acreage by hand. Would casual labour for the other half be cheaper than the extra equipment, costing perhaps £350 ?

Having finally decided upon the pattern of equipment and labour, there remains the question of how much needs to be purchased new. Perhaps most of the cultivating equipment and one tractor could be second-hand, but it would almost certainly be best to rely on new equipment for the really critical periods—the two harvesters, for instance. By judicious buying, this figure might be reduced to under £4,000, nearer £15 per acre. This figure has, in fact, been regarded as a " target " for mixed arable farms for some time.[3] If grain storage and drying facilities have to be included, it is unlikely to be achieved, but some figure between £15 and £20 per acre is the normal range for farms where careful thought has been given to the pattern of mechanisation, while figures double this have been not uncommon, in fact.

Costs of Operation

Once the pattern of equipment has been decided upon, the expected costs of operation can be easily calculated, for they will stem directly from it. Operating costs are made up of depreciation, repairs and fuel. The latter is a relatively small part of the whole, rarely more than 15% of annual machinery costs, whereas the other two are directly related.

Depreciation is a term which is much misunderstood. To accountants it is primarily a method of amortising capital expenditure. To most farmers there is an idea of " wear and tear " involved. But the accountants' view is the more correct. Depreciation should be a form of financial discipline to make sure that the business does in fact pay off capital investments and in a fairly short period. Repairs are carried out to maintain equipment and prolong its useful life. It follows that as machines get older the proportion of repairs to depreciation rises. In all that follows, a flat rate of 20% of purchase price is taken to cover depreciation and repairs.

Having assessed the value of machinery inventory, it only remains to take one-fifth as the expected annual cost. In the case of our example, even if all the equipment were purchased as new, the rate would be £4 4s. per year. If the rate of 20% is considered too low, 25% only raises the figure by just over £1 per acre. This can be compared with the rates found at present on different types of farm.

If the differences do not seem very large, it is worth noting that these depreciation charges here are based on *written down* values and even with repairs do not amount to

[3] D. B. Wallace, *Farm Mechanization*, Dec., 1959 ; Jan., 1960.

20% of original cost. Even so, the rate for our example is £2 per acre below the average, which might increase profits by 20%.

Table II
MACHINERY COSTS PER ACRE, E. COUNTIES

Type of Farm	*Depreciation and Repairs per acre*
	£
Arable, little Livestock	
Alluvial	8·9
Mainly cereals	5·5
Mixed arable	6·6
Arable and Livestock	
Mainly dairy	6·7
Dairy, pigs and poultry	8·2
Pigs and poultry	8·2

Source : Farm Economics Branch, Cambridge.

What is the cause of these differences? It is undoubtedly due partly to piecemeal mechanisation discussed above, so that cropping, labour and equipment have not been integrated properly. But three other factors operate as well. On most farms, as time passes by, machines are carried when they are really of little use any longer. Inventories are not cleared and much redundant equipment remains, carrying a paper depreciation rate. Then many farmers operate what can only be called a " belt and braces " policy. Far more equipment is kept than is strictly necessary. A second combine, extra tractors, standby implements, even additional labour, all to be on the safe side. Finally, many farmers make a fetish of replacements. The depreciation costs, under our fiscal system, are far higher in the first two years of life. As long as profits are made, many farmers feel that one form of hidden reserve is to re-equip at short intervals. Yet repair costs do not rise as fast as depreciation falls over, perhaps, the first six years of equipment's use.[3]

Conclusion

It is now time to close this discussion and try to answer the questions posed at the start. How much machinery can a farmer afford? There is no simple answer, for so much depends upon the circumstances of the farm. Each farmer can answer this for himself by going through the process outlined above, deciding what is the minimum of labour and machinery that would enable him to get by with his cropping and stock pattern if he started afresh. Thus he should decide what he would need to spend to get this inventory, and set out over the years to achieve that level, disposing of and not replacing surplus machines. This may take time, but he will have a target to which to work. In normal circumstances, the capital cost of arable equipment should lie in the range £15 - £20 per acre at *purchase* value—*not* as written down in the balance sheet after a number of years.

As time progresses, some equipment will need to be replaced. The farmer must keep up with the times and take advantage of new techniques if they will improve the integration of labour and crops. But far too many indulge in new and more expensive equipment, which does *not* reduce labour costs over the year, but raises the depreciation instead. This is because they do not look on the labour and equipment as a whole, common to the farm and its various enterprises. It is safe to say that most farmers to-day have over-full inventories, and in that sense are over-mechanised. But it is not really over-mechanisation—it is values really that they have mechanised wrongly.

Summary

Machinery accounts for up to 25% of total annual costs on British farms to-day. With tightening economic circumstances ahead, some way of reducing these costs must be found. Machinery works with labour to aid production, and the two must be considered together. Most mechanisation on arable farms has been of a piecemeal nature, individual operations being mechanised without thought to the overall pattern of cropping and consequent labour demand. As a result, arable areas have not shown the reduction in labour that might have been expected.

To overcome this, a farmer should examine systematically the minimum number of men and machines required for the major operations in his cropping year. Once he finds the sector causing the highest labour demand, he should plan either to reduce that peak or accept it, and plan his other operations in the light of it. All other equipment should be sold. Annual costs can be held down by buying wisely and keeping up maintenance routines. A target figure for arable farms should be £15 - £20 per acre for equipment giving annual costs of about £5 per acre. These rates are well below the average of to-day, but are achieved by farmers who have integrated their machinery, labour and crops.

DISCUSSION

MR. J. H. COCK (East Anglian Real Property Co.), the Chairman, said he was sure it was refreshing to have an economist talk to the Institution, because from the farming and engineering point of view it was necessary for an economist to tap the shoulders to curb enthusiasm and to set them thinking about the whole development of mechanisation. This had gone forward in very piecemeal stages. However, although Mr. Wallace had said that he was taking the hypothetical case of sitting down and starting from scratch, it was true that few people could do that.

It had taken a long time, said Mr. Cock, to adjust the farming programme to the present stage of mechanisation. He mentioned the latest developments in prime movers, but added that crawler tractors had not changed as much as wheel ones. However, it was only now that they were getting to the final stage of developing equipment which tacked on to these prime movers, such as reversible ploughs and the like. And when the final stage was reached, some new development seemed to turn it topsy-turvy. As an example of adjusting a farming programme to equipment, he quoted a case on one of his company's farms. Output from two harvesters had been roughly 50 per cent. of that on light land farms.

It had only been by adjusting the programme and releasing the two harvesters on the heavy land farms early that production could be increased.

He said he did not think that labour and mechanisation had been very well integrated with modern methods, because things had not been planned in their entirety. In this transition period they were trying to bring up to date the management side of farming with personnel who had other ideas stabilised over the last 50 years.

Mentioning the introduction since the war of the combine harvester, he said that one would have supposed that equipment used only for a month in a year should have a very long life. He was glad to hear Mr. Wallace giving 10 to 15 years as a figure. He asked if Mr. Wallace felt that the present trend in machinery in terms of size of unit was right, and whether he thought it might be necessary in manufacture to design equipment larger than required for the individual farmer, even if that meant not building for the individual farmer.

MR. WALLACE replied that on the question whether the present trend in size of equipment was right he was not *au fait* enough to know what the present trend was. But he thought that a trend towards smaller equipment was wrong. This coincided with earlier remarks of his when reading the Paper—that it would be more economical for the public to use public transport, but that frequently they preferred to use their own. Similarly, everyone wanted his own combine.

He used to think that so many acres were wanted per cutter bar. But then he met a farmer who had only 20 acres, but whose combine had only cost £15. It had cost that because he had been going to buy a set of disc harrows. That sort of thing undermined technical argument. But he thought it was generally true that it was better to go for large machinery ; it was not possible to have the sort of giant machines that the Russians produced, but something like that all the same. The trend in the next 20 years would be towards much bigger farming units, and a company could reasonably have large units of machinery which could be deployed across its holdings. The trouble was that the turn-over in agriculture was so small and that the number of big units needed was so small that manufacturers might feel it was not worth bothering about. It was, however, a question of the chicken and the egg. If the economies resulting from large machines were not available, then the small units would not be combined. Someone had got to be brave, and he did not see why the manufacturers of machinery would think it should be them.

MR. H. G. PRYOR (Essex) asked Mr. Wallace if he would discuss the subject of standardisation. Mr. Pryor felt that if a standards policy could be enforced on manufacturers it would have a big effect on the mechanisation of farming.

MR. WALLACE said that everyone was in favour of standardisation on the Henry Ford principle : "You can have any colour you like as long as it is black." All were in favour, providing it was not they who were affected. The theoretical savings could be great indeed. Mr. Pryor was right, but it was not practicable.

MR. D. R. BOMFORD (Worcs.) queried the figure in the Paper of £2,500 as being a reasonable capital expenditure to replace one man. He assumed that this related to the saving of one man throughout the whole cycle of the year. They had been told also about peak load periods of the year, and it could be true that, in shaving off the peak, that amount might be saved. But Mr. Bomford asked if they were not losing sight of the problem of peak loading. Certain tasks, such as harvesting, must be done at a certain time. Many other jobs could be moved about to fill the troughs, such as hedging, ditching, trenching, repairs to buildings and roads, and these could be placed in the troughs at any time one might choose. Consequently, peak and non-peak jobs had been distinguished.

However, asked Mr. Bomford, were not those movable jobs also peak loads, because to-day, if one did not have the machinery, they did not get done ? So, referring back to the £2,500 figure, it was difficult for that sum to buy machinery which would save a man all the year round, peak and non-peak. Considerably higher figures had been given by economists for that figure.

MR. WALLACE replied that he obtained his figure by multiplying £500 by five. If Mr. Bomford said that one could not obtain a man for £500, then the figure was altered. He thought that they were basically in agreement. What he had been trying to say was that there seemed little point in mechanising purely to save labour. But if that labour could be saved right through the year, then one could afford to spend £2,500 on equipment—hedge-cutter, things that were stamped up and down on the road, or anything else. He was not suggesting the £2,500 should be spent on one piece of equipment, but if one could think of various pieces which would save one man out of one's organisation, it was economic.

MR. J. M. CHAMBERS (Warwicks.) drew attention to a remark of Mr. Wallace's about the quality of farm machinery which the farmer could not afford to buy. This implied that a cheapening in the quality of farm machinery was required. Later, Mr. Wallace had recommended a streamlining of the inventory. But if it was wanted to streamline the inventory, top-quality machines were required on which the farmer could depend ; so the two things were not compatible. The machines needed to be reliable and able to do the many jobs machinery in this country was required to do.

MR. WALLACE pointed out that it all depended on how cheap was meant by "cheap." He was not suggesting that machinery should be made out of expendable material. His point was that in a great deal of cultivation equipment, if one looked at the bearings they were really pretty crude. To put in high-grade roller bearings might not be justified.

MR. NOLAN was sure that Mr. Wallace had rendered them a valuable service in getting the conference off to a good start. He had been amused at a reference of Mr. Wallace's to "Swiss watch engineering," and how undesirable that was in agricultural engineering. It was, said Mr. Nolan, a nice way of paying a compliment to British agricultural engineering. What had emerged from the Paper was the cost of mechanisation in the modern age, and he was sure that as those present read the Paper they would learn a great deal about what the future held for them.

DEVELOPMENT IN MECHANISATION AND MECHANICAL HANDLING ON THE FARM

(Graduates' Session)

(I) MILLING AND MIXING ON THE FARM

by D. J. B. CALVERLEY,* B.Sc. (Agric.), M.Sc. (Agr.Eng.)

ALL too often in the past farm machinery has been bought without any clear thought as to the effect it will have on the cost of doing a particular job or whether there will be any increase in net profitability of the enterprise or holding. Before the purchase of any single machine or the mechanisation of any farm process, a number of questions have to be asked and satisfactory answers given. Only then should capital be spent and the machinery bought. Applying this broad concept to milling and mixing on the farm, the questions to be asked are :

1. Is the operation going to show any saving, a gain in profitability, saving of time or more efficient use of available material ?
2. Are machines available that will do the required job, and what existing routines and practices have to be changed ?
3. How can the machines be installed to the best advantage ?

This Paper sets out to try and present the answers to these questions in the light of present-day knowledge and machinery, and what possibilities there are for future developments.

Costs

This has been and still is one of the most controversial points in any discussion on the merits of farm milling and mixing. To consider objectively whether food compounded on the farm compares in cost with that produced by national or commercial compounders, three items of cost have to be considered.

1. Ingredients.

2. The capital value of the equipment, which will include not only the machinery, but any modifications or alterations to the building and the supply of power. The estimated life of this equipment will give the fixed costs.

3. The annual throughput of the plant to give the variable costs.

The greatest proportion of the variable costs will be the grain produced on the farm, and this must be considered at its market value. As if production costs are higher than the market value the farmer would be better using the land for some other purpose and buying grain on the market for processing. Even allowing for the price fluctuations of barley, the guaranteed price of both wheat and barley will increase during periods of storage. Usually the consumption of concentrate feeding-stuffs is at a constant level throughout the winter, and an average price must be assumed for grains stored over long periods. There is no case for including grain at cost price. There have been so many exaggerated claims of potential savings, one suspects this concept of cost is not held by everybody. The remainder of the ingredients will be of purchased foods, usually proteins, minerals, etc.

The capital cost of equipment will depend upon the size of the installation. To consider one example, a small combined mill and mixer with a throughput of 100 tons per annum can be installed in an existing building for about £400. The life of this type of equipment has been variously estimated between five and ten years, the longer period probably being the more realistic. Over a ten-year period the depreciation is £40 per annum. Money will be borrowed to purchase this machine, and interest will be paid on the diminishing debit balance, or the same money would have been available for investment elsewhere and income through interest on this investment will be lost. In either case, there is a further annual fixed charge on interest on the capital ; at 6%, this is £12 per annum, giving a total fixed cost of £52.

The annual throughput of the machine will determine the maintenance and variable costs. Even after many years of farm use there is no reliable guidance to maintenance costs. Some authorities allow an arbitrary sum of 3% of the capital cost, assuming that there is a linear relationship between throughput and initial cost. Wakeford suggests £15 per annum up to 250 tons processed meal per year, £20 per 250–500 tons processed per year and £25 over 500 tons ; these figures to cover the cost of insurance. Culpin quotes 7½% to cover the cost of depreciation and repairs. The only real point of agreement seems to be that it is a very low figure and will have little bearing on the final analysis. The 3% on capital cost seems to be a sufficiently satisfactory approach and is simple to apply.

The running cost is simply the cost of electricity (unless tractor or engine-driven units are considered). Except in the case of units where the mixer is required to run continuously as a means of conveying from the

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mill, mixing can—as discussed later—be considered complete in 30 minutes at a specific electrical consumption of 2·5 kW.h. per ton. The output of the mill, and consequently the consumption of electricity, will vary with the fineness of grinding. The specific consumption per ton ground varies from 18 kW.h. for coarse grinding to over 50 kW.h. for very fine grinding. Allowing 30 kW.h. per ton of ground meal and that 75% of compound food is to be milled, the consumption of electricity for milling cereals per ton of compound is 22·5 kW.h. The total consumption per ton of compound is 25 kW.h., and at 1½d. per unit the cost is 3s. 1½d.

If we continue our example on the basis of 100 tons throughput per annum, the machinery costs can be summarised thus :

	£	s.	d.
Fixed Costs—Depreciation ..	40	0	0
Interest	12	0	0
Repairs at 3% ..	12	0	0
Running Costs—Electricity ..	15	12	6
	£79	12	6

The cost per ton of compounded food, 16s.

These figures relate to the conditions specified in the example and they are intended as a guide to the method of arriving at an accurate costing for any intended installation. In practice, it will be found that the figures given for specific consumption of electricity are surprisingly constant, and that 15s. per ton inclusive cost for machinery can be taken as a sufficiently accurate guide for approximate calculations. The example infers the use of a hammer mill, but any mill or grinder should be subject to the same process of analysis.

There is a further and rather nebulous factor to take into account—the apparent loss in weight during compounding. This loss can occur in two ways. First, a loss of moisture due to the grain being heated in the mill and then conveyed pneumatically, the warm, finely-divided particles of meal easily losing moisture. Secondly, a loss of the finest particles which are not retained by the cyclone or any system of dust filtration. Commercial compounders will admit to these losses even in well-designed and maintained systems, and amounts of 2% - 5% have been quoted. There is no substantial evidence to show what these losses are on farms ; *ad hoc* investigations suggest they can be as high as 7% - 10%. This is certainly due to material loss and is due to bad design and installation of plant. It is certainly true that farm compounded rations will have a higher moisture content and thus lower nutritive content than commercial compounds which include foreign grain. It is suggested that 10s. per ton be added to the cost as a contingency to cover these losses.

Adding these items—Materials
Fixed costs
Variable costs
Contingencies

the total can be compared to commercially available rations and any possible savings assessed. Table I shows two pig rations suggested by the Pig Industry Development Association for home compounding compared to the average price of six commercially available equivalent rations. The prices are as ruling in March, 1962, and it is worth noting the potential saving with barley even at this elevated price.

Table I

P.I.D.A. RECOMMENDED RATIONS COMPARED TO COMMERCIALLY AVAILABLE COMPOUNDS

		£	s.	d.
Fatteners				
15 cwt. Barley at 22s. 6d.	..	16	17	6
3 cwt. Wheatings at 26s. 0d. ..	..	3	18	0
1½ cwt. Soya Bean Meal at 40s. 0d.	..	3	0	0
½ cwt. Fish Meal at 68s. 0d. ..	..	1	14	0
28 lb. Mineral at 30s. 0d.	..	0	7	6
Grinding and Mixing	say	0	15	0
Loss in Weight and Contingencies ..	say	0	10	0
		£27	2	0
Commercial Rations	..	£31	0	0
Saving	..	£3	18	0
Sow and Weaners		£	s.	d.
12 cwt. Barley at 22s. 6d.	..	13	10	0
6 cwt. Wheatings at 26s. 0d. ..	..	7	16	0
¾ cwt. Soya Bean Meal at 40s. 0d.	..	1	10	0
1½ cwt. White Fish Meal at 68s. 0d.	..	5	2	0
28 lb. Mineral at 30s. 0d.	..	0	7	6
Grinding and Mixing	say	0	15	0
Loss in Weight and Contingencies ..	say	0	10	0
		£29	10	6
Commercial Rations	..	£33	0	0
Saving	..	£3	19	6

Two further points emerge from this comparison :

(*a*) The relatively low cost of the machinery, less than 3%. If we include the contingency allowance, it is still less than 5% of the total cost. It would seem that machinery costs could rise to over £4 per ton and still maintain a margin.

(*b*) The omission of labour costs. It is becoming more widely accepted to consider labour as a farm overhead instead of allocating its cost to each and every farm task. The case for including labour costs exists only where labour is specifically employed for this work, which will happen on large farms with a high annual throughput where one man is fully employed, or smaller units where it becomes an overtime or piece-rate task. There is a further and final point to consider when an estimate of potential saving has been prepared—that is, to consider the saving in relation to the conditions on the farm, particularly on small farms where labour is more intensively worked than on larger units, and the average throughput is likely to be small. The capital to be spent may yield better returns in other forms of investment. More stock, alterations to old or putting up new buildings, other machinery, etc. The labour or the entrepreneur may be so fully occupied that to introduce an additional routine task would upset the balance and cause dislocation of other work. These considerations cannot really be generalised upon—they are specific to each holding.

Equipment

(*a*) *Hammer Mills*

The advantages of hammer mills were defined as early as 1922, but it is only in the last decade that the development of the small automatic hammer mill has led to its wide use and the tremendous growth in farm compounding. There are many numbers of different makes and models available, usually powered by a 5-h.p. or less, but occasionally larger, electric motor. They are capable of complete automatic control, starting in the evening to take advantage of lower night tariffs and stopping when grinding is complete.

The selection of a mill is almost completely determined by its capacity to grind sufficient corn in the available time. Fifty hours per week is the optimum period to allow. This will enable all grinding to be done at night and still give a margin for day use when it is necessary to accumulate meal for holidays or other temporary dislocations of routine. A useful guide is to allow about 1 cwt. per hour per h.p. medium grinding of wheat, barley a little less, and oats about $\frac{2}{3}$-cwt. per hour per h.p. Very fine grinding will reduce the output by almost half. The need to grind fine is a matter of debate and is related to the stock to be fed. Oats and to a lesser extent wheat are recommended to be ground very fine on account of their higher fibre content. Suggested screen size is $\frac{3}{32}$ in., but in England we tend to grind much finer than on the Continent or America. Biological experiments on the need for fine grinding have provided conflicting results, but there is some agreement that too fine a grinding for ruminants will cause digestive upsets. Suitable screen sizes for all classes of grain will probably be $\frac{3}{32}$ to $\frac{1}{4}$ in. A compromise must be reached, otherwise the screen will have to be changed for two or more types of grain mixed for a single ration.

Consideration must be given to the material to be ground. With a dirty sample which contains straw, it can reduce the output to nil by the mill entry being choked. Even a few straws will cause a complete blockage, so clean grain is essential. The recent advances in combine and pre-cleaner design should be sufficient to reduce this problem for home-stored grain. Another difficulty less easily dealt with is the blockage of the mill caused by fine grinding of some varieties of oats. The N.I.A.E. tested mill performances with Onward as a low kernel, low oil content variety, and Grey Winter as a high kernel, high oil content variety. With the same screen size, not only did Grey Winter appear coarser, but the meal was stickier and produced blockages in a very short time ; Onward was ground quite satisfactorily. Wakeford quotes S.147, S.172 and Sun II as oats which are difficult to grind. Where possible, it is recommended that these difficult varieties are mixed and milled together with wheat or barley.

(b) Plate or Burr Mills

These have now gone completely out of use on farms wanting automatic plant. They could not be easily adapted to automatic feed on account of the necessity to maintain grain between the plates. If the corn supply failed for only a short time, overheating and damage to the plates would result. Nevertheless, they were preferred by many on account of the coarse grinding or kibbling they did without producing dust. One firm has satisfactorily overcome this problem and now produces a small automatic rolling and plate grinding mill. This is mounted over the top of a mixer which acts as a storage bin.

(c) Automatic Rolling Mills

There is a small but significantly increasing demand for this type of unit which will produce a much less dusty product than a hammer mill. The action of rolling grain produces no in-built system of mechanical or pneumatic conveying, so that additional equipment is needed to provide material flows to and from the unit. A recent and most notable advance has been the successful development of a roller mill mounted over a hammer mill, a single motor driving both units. When rolling grain, the material falls into the pneumatic conveying system of the hammer mill and can be blown wherever is convenient.

The essential feature of rolling or crushing is that, although the kernel of the grain is exposed and divided to aid digestion, the essential structure of the kernel is preserved. It is more easily and quickly assimilated than dusty material, and on this count appears to be preferred by stock. To obtain the desired results, the optimum moisture content of the grain is about 18%. Dryer than this, the kernels shatter and the result is akin to very coarse milling. Unfortunately with bulk storage of grain, the safe maximum moisture content for storage has fallen to 15 – 16% for bins and 14% for loose heaps on the floor. If this material has to be satisfactorily rolled, moisture must be added to the grain. The technique is not difficult, but in calculating how much has to be added it must be remembered that moisture contents are usually expressed on a wet basis. To increase moisture contents from 14% to 18%, 4·75% of moisture has to be added to the dry grain, or 10·4 gallons per ton.

Where large quantities of rolled grain are to be fed, the grain can be stored at moisture contents of up to 24%, providing that air can be completely excluded. A number of gas-tight silos are available on the home market, ranging in cost from £8 10s. per ton grain stored to over £15. This is high compared with conventional storage bins at £5 – £6 per ton stored, and suffers from the further disadvantage that this grain can be used only for stock feeding.

(d) Cubing and Pelleting Machinery

Until recently, this was one process of farm compounding denied to moderate or small-sized farms on account of the very high initial costs and the elaborate facilities needed to produce satisfactory cubes. The small farm cubers now available are developments of the larger commercial compounders machines where the meal is extruded by means of rollers through holes in a perforated annular or die ring. A new principle was introduced in an N.I.A.E. prototype, where a piston extruded meal through a parallel sided die tube. This, it was claimed, would reduce die cost and the heat content of cubed material reducing or eliminating the need for a cooling period.

All farm cubers will now successfully operate without steam as the binding agent ; in many cases satisfactory cubes can be made without any binding agent, providing they are not to be stored for long periods. Five per cent. of molasses, diluted if necessary with an equal volume of water, gives adequate cohesive strength and can be used to bind grains in any condition suitable for stock feeding. Such a mixture tends to " set " after a time, and continuous or intermittent agitation is necessary.

The cost of cubing can be assessed as for the mill described earlier. An electrical consumption of ·6 kW.h. per cwt. or 12 kW.h. per ton of cubes, about half that for pellets, has been claimed for some recent plants, but this is lower than for older installations. Die wear varies with the abrasiveness of the meal ; it is particularly acute if it includes dried grass, and thus can be related only to specific commodities. In practice, 250 to 350 tons per set of die rings and rollers is a reasonable figure on which to budget. The cost of replacement is about £70 or 4s. 6d. to 5s. per ton. The total cost of pelleting 200 tons per annum in a plant costing £400 will be about 13s. 6d. per ton.

(*e*) *Mixers*

There are three types currently available—the traditional horizontal mixer, which can be used for both wet and dry mixes, the popular and almost universal vertical mixer, with the central auger acting as the elevator for filling and agitator for mixing, and a " conveyor mixer," in which agitation is provided by a moving chain and slat conveyor inside a rectangular chamber.

N.I.A.E. tests have shown conclusively that farm mixing with any type of mixer can be done to a standard to satisfy even the most stringent of requirements. The simple rule for successful operation demands only that constituents forming a very small percentage of the total ration are premixed, if necessary, by hand with a quantity of the major ingredient and fed in when the mixer is about half full. The time taken to achieve the optimum mix is 15 to 20 minutes in a vertical mixer and three to five minutes in a horizontal mixer. Longer periods may cause some separation of ingredients.

Installation

All too often on farms is it possible to find cases where the full potential of automatic farm compounding plant is not being achieved through careless and thoughtless installation. The major fault is that equipment is designed round the sack as the only means of getting grain to the mill and removing the compounded food. It is astonishing that whilst bulk deliveries of feeding stuffs from commercial firms are contemplated as the alternative to farm compounding, the same bulk handling techniques do not define at least some of the design parameters when laying out a farm installation. The overall consideration is that farm compounding is a composite operation, including a number of treatments, and that while the selection of treatments will depend upon the individual requirements of the farm, they are all essentially related and must be properly linked together.

The individual treatments may be listed :

1. Pre-mill storage.
   1a. Quantitative measurement.
2. Milling.
   2a. Quantitative measurement.
3. Pre-mix storage.
4. Mixing.
5. Pre-cube storage.
6. Cubing.
7. Pre-feeding storage.

The variation that is possible with these treatments and range of equipment is infinite ; for example, the mixer may be used to provide pre-mix storage and pre-cube storage, or where only one ration is being compounded pre-feeding storage. It is not possible in this Paper to discuss all the relevant details ; the following points are considered to require particular attention :

Measurement of Ingredients

This has not been given the attention it deserves by manufacturers or installers. Reasonably accurate control of the commodities being fed is essential for correct feeding and economy. The measurement can be volumetric or gravimetric and be of grain or meal. On this account, it is usually associated with the storage of either, and graduated hoppers often provide the simplest solution. An example of a flexible volumetric method is to arrange for two or more pre-mill hoppers to be filled *via* a bulk conveyor. The quantity in each bin can be varied by fitting an outer sleeve to the outlet spout of the conveyor discharge, which can be raised or lowered at will. The overflow from the spout is arranged to discharge into the other or adjacent bin. This system allows any number of pre-storage bins to be arranged for different rations within the limits of flow to the mill, and by virtue of the overflow arrangement eliminates the need to have precise shut-down of the conveyors. A similar system can be used for meal, the conveyor being filled from a cyclone, and as each bin fills the meal is conveyed along to the end. When the end bin is full, a pressure or diaphragm switch stops the conveyor and mill. This is particularly useful where the mill is fed from a large capacity pre-mill store. Both these arrangements are capable of considerable elaboration.

In the simplest installation, gravimetric measurement is achieved by weighing the grain in sacks or in bulk containers. Integrating flow measurements on larger installations have been possible for some time with automatic weighing equipment, but rarely installed because of the cost. Recently, an integrating flowmeter has been developed working on the principle of an overshot water wheel. This is a compact unit which can be fitted easily into most existing installations and can be fitted with electronic devices for automatic control. A conversion kit is now available to make sack weighing machines semi-automatic and capable of electric control.

A recent innovation from America is a system of feeding the mill by a number of variable output auger conveyors. Where a range of feeds have to be milled, this system ensures the continuing correct proportion of each, and if all the commodities can be fed through the mill the meal after grinding is already mixed. A similar system using vibratory feeders instead of augers is also in use, but too few of these plants are on farms to be able to give balanced comment on their performance.

Dust

Not only is this a nuisance, but it must be considered as a hazard to health. The broad principles of dust prevention have been established for some time, and it is in this instance more to the discredit of the farmer than the engineer that such dirty plants are still to be found. The chief faults are usually poor maintenance and sometimes bad installation, such as ill-fitting connections on the pneumatic pipe work, a cyclone discharging to the atmosphere without dust filters or inadequate filters, open conveyors and bins into which meal or grain is discharged, and where meal bins are home made or vertical mixers used as pre-mixing storage, poor finishing of the joints allowing leaks. Adequate ventilation either through open doors and windows or extractor fans will have some remedial effect, but will not compensate for positive dust leakage.

Layout

In planning the layout, sufficient space has to be allocated for each treatment or stage and the siting of the machinery considered to give good material flow. Space is needed for :

Storage of grain.
Storage of bought-in concentrates.
Machinery.
Storage of compounded foods.
Containers used for meal transport.

On many farms it has been possible to include the compounding plant in the grain store, but where this is not possible the grain store and compounding machinery should be as close as possible. Other considerations being equal, it is less bother to move grain to the mill than meal to stock. The site needs good access by road, not only for farm tractors, but for lorries bringing concentrates. Space for the storage of this should be near the door and the mixer.

Space allocated for the machinery will be a minimum if a combined mill and mixer unit is installed, but there should be enough room to add a further unit or more equipment if food consumption is likely to increase for any reason. Where one ration only is being fed, the mixer may be used as a pre-feeding storage, otherwise separate storage will be needed. This may take the form of conventional meal bins, but box pallets, which with a pallet truck make a feeding trolley, or feeding hoppers built as special-purpose pallets and handled on the farm tractor are some alternatives that should be considered to the sack and provision made accordingly.

(II) THE INCREASED USE OF MECHANICAL HANDLING EQUIPMENT AND TECHNIQUES

by G. C. F. Howe,* N.D.A., S.D.A., N.D.Agr.E.

Introduction

It has been estimated that on farms in this country between 30% and 50% of man and tractor hours are spent on the handling and movement of materials. With a decreasing labour force, increasing labour costs and lower expected returns for many commodities, some means of reducing this figure is essential if farming is to remain profitable. Mechanical handling can play a large part in realising this, provided sufficient thought and study is given to ensure that it is justified practically and economically.

Materials handling in agriculture is particularly difficult, due to the very wide range of products, in relatively small quantities, to be handled, the handling characteristics of which vary greatly. The design of many farm buildings, and the conditions over which materials may have to be transported, make it difficult to design equipment equally applicable to all conditions. A materials handling problem must not be considered in isolation, as it may only be one in a series of operations necessary before the commodity is used or sold. Equipment must therefore be integrated to form part of a co-ordinated system aimed either at reducing labour or increasing its productivity. To justify the cost of this equipment, especially on the smaller farm, the number of enterprises should be reduced, while the remainder should be expanded.

Because this subject is large and limited time is available, it is possible to discuss only a few commodities which seem to offer the greatest scope for labour saving and where development seems most likely. First, however, some materials which have already been mechanised successfully are discussed.

Grain

Due to its relatively uniform nature and free-flowing characteristics, grain is ideally suited to handling in bulk. In some cases, handling of grain has taken place in a piecemeal fashion, resulting in poorly-planned installations. The high capital involved is difficult to justify on the smaller mixed farm. Some co-operative units have been installed and appear to work successfully in practice, and this may provide a solution for these farms.

For the smaller farmer, handling in sacks should not be disregarded, as the use of simple pallets can eliminate much of the hard manual work often connected with sack handling.

Sugar Beet

Although sugar beet does not possess the same free-flowing characteristics as grain, it has been possible to mechanise the growing and harvesting of the crop, with

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the elimination of practically all manual labour. The harvesting of the crop does not present any serious difficulties, since the main object is to deliver beet to the factory with as little dirt tare as possible. The use of front-mounted tractor shovels and cleaner loaders help to achieve this end.

A modified bulk handilng system using stillages has been tried and may offer possibilities for the small producer.

Milk

Milk is ideally suited to mechanical handling, particularly with modern equipment and techniques, such as the use of a parlour in conjunction with the in-line system of milking incorporating bulk storage.

It can be seen that the main reason for progress in the use of mechanical handling equipment and techniques for these products is their inherent suitability. Furthermore, these products, particularly sugar beet and milk, yield a direct cash return and the farmer is in a better position to assess whether or not mechanical handling equipment is justified on economic grounds.

Hay

Grass is the most widely-grown crop in Britain and constitutes the greatest and cheapest source of cattle food throughout the year. Many developments are aimed at overcoming its non-free-flowing characteristics. Considerable research on improvement of hay quality has been carried out lately, and the result has been widespread adoption of quick hay-making techniques. The handling of hay has progressed much less rapidly, and little has been done since the advent of the pick-up baler. This, in overcoming some handling problems, introduced many more, especially in connection with bale handling. At present a wide variety of machines and systems is available to the farmer. The best of these seems to be the use of a sledge, towed behind the baler, producing uniform heaps of bales directly or indirectly. The heaps are later picked up by means of front and rear-mounted buckrakes and transported directly to the farm or, alternatively, loaded on to trailers in the field.

Two fairly new methods seem to offer distinct possibilities ; the first involves the use of a bale-throwing device, attached directly to the rear of the bale chamber, for ejecting half-sized bales into a trailer drawn behind. The bales falling at random make it difficult to achieve a reasonable load—hence trailers with high sides are necessary. When unloading, the bales are fed on to an elevator and allowed to fall at random in the barn. This system can result in a low labour requirement, but higher cost of equipment and increased storage space. Another recent development is the pallet system.

Hay pelleting has been developed in the United States, and is aimed primarily at reducing transport costs. Hay in this form lends itself to mechanised handling and feeding, and greater live-weight gains have been recorded when fed to beef cattle in place of hay in its normal state. This has been attributed to the greater intake of dry matter. Results have not been so encouraging with dairy cattle, as it appears to cause a lowering of the butter-fat content of the milk.

Hay wafering has been shown to obviate this disadvantage, while being admirably suitable for mechanical handling and feeding. The reason for this is that the hay need not be ground to such a fine state as is necessary for pelleting. Before wafering machines can be operated commercially in this country, considerable research will be necessary to ascertain the type of plants and optimum moisture content best suited for this process and the shape and density of wafer most suitable for feeding and mechanical handling. From American evidence, it would appear that legumes are more satisfactory than grasses, as the leaf/stem ratio is higher, allowing better binding of the wafer and reducing spring-back. The hay should be processed at a moisture content of 15–25%, producing a wafer with a density of around 40 lb./cu. ft. Density is especially important, since if too high it results in difficulty in eating, while at the other extreme the wafer may fall apart when handled.

In the British Isles, difficulty may well be experienced in reducing the moisture content sufficiently in the field. If wafers are to be used as part of a system aimed at complete mechanical feeding, it may be worth considering the addition of a supplement during wafer formation to provide a complete ration.

Silage

The quantity of grass conserved as silage is low compared with hay, but as regards mechanical handling has received much more attention. One of the greatest advances has undoubtedly been the introduction of the forage harvester, which not only greatly facilitates handling, but also helps in the making of better silage. Up to the present the most popular forage harvester has been the flail type, due to its extreme simplicity, robustness and versatility, combined with a relatively low cost. A proportion of the resulting lacerated material is too long for efficient handling, particularly if mechanical feeding of livestock is contemplated. The material must be short and of uniform length to overcome the problem of interlocking and facilitate mechanical extraction from the silo and conveyance to feeding troughs. The double-chop harvester employing a flail-type cutting mechanism and chopper blower to some extent provides a solution, but the material is still of varying lengths and is not entirely suited to mechanical feeding. The most satisfactory method may be to employ a cutter-crusher to obtain a high rate of moisture extraction, and pick up the wilted material with a chopper harvester fitted with a pick-up attachment.

Handling the silage from field to silo offers no particular problems. Self-unloading forage waggons, used in conjunction with a blower or chopper blower, seem to be suitable for both pit and tower silos. A reasonably uniform density in the silo is obtained—an important factor, particularly in towers employing mechanical unloaders to provide an even power requirement and the relatively steady unloading rate necessary if the silage is metered on a time basis.

Many mechanised feeding layouts, using tower silos and mechanical unloaders in conjunction with conveyor feeders, are being installed in the United States, but it is doubtful if installations of this type will become widespread in this country, for the following reasons :

(*a*) The proportion of dairy cattle to beef cattle is high in this country, and it would appear that the system is better suited to beef production.

(*b*) Maize silage is easier than grass to handle mechanically.

(*c*) Existing silos in this country are predominantly of the clamp type, so that farmers here are more likely to seek some form of mechanical feeding adaptable to this type.

(*d*) American farmers often mechanise merely to eliminate manual labour, whereas their British counterpart is more concerned with return on capital.

As in wafering, if mechanised silage feeding is to be a step towards the complete elimination of manual labour, it is worth while considering the installation of a unit for introducing supplements to provide a complete ration. It is interesting to note here that an important materials handling principle is involved—namely, the integration of processes, in this case mixing supplement with silage as it is being conveyed.

A difficulty yet to be overcome satisfactorily and economically is a means of metering the quantity of silage fed. The most accurate method in use at present is weighing, then measuring by volume, and finally the least accurate, " timed " from the silo. A unit being developed in the United States at the moment, which seems to offer distinct possibilities, calculates the electricity requirement for unloading a certain quantity of silage. Supplements are easier to measure accurately because of their better flow characteristics and greater uniformity. The device used at present for this task in order of accuracy are the auger, moving belt and vibrator. Units are also available which grind and mix different foods in varying proportions before introduction into the silage.

A side discharging forage waggon used to deliver silage into troughs would seem to be attractive for the feeding of cattle in yards. Not only is it suited to clamp silos, but also involves less capital outlay and spreads the overhead costs.

The main drawback to this system is the lack of a suitable machine for unloading silage from the pit. Of the two current possibilities, the use of a tractor-mounted hydraulic loader fitted with a silage fork is simple and deals effectively with well-chopped silage. It is, however, non-continuous in operation, and the silage tends to be extracted in lumps, with consequent difficulties in feeding. The second type involves the use of a rotary cutter working on the silage face and delivering to a conveyor for loading the waggon. The unit is continuous in operation and the cutting action renders the silage more suitable for handling and feeding. If supplements are spread evenly over the silage in the waggon they will be mixed fairly thoroughly as the load is being discharged.

Such a system would appear better suited to the feeding of beef cattle, although the time may come when individual feeding of dairy cows according to performance is discontinued, and feeding based on a standard milk yield adopted. Feeding concentrates in the parlour would then not be necessary. The adoption of mechanical feeding of silage will reduce difficulties of rationing and help to cut out waste, often associated with self-feed silage systems.

One of the main time-consuming jobs connected with livestock tending is the carting and spreading of litter. This can almost be eliminated by the adoption of the Gülle system of manure disposal in conjunction with organic irrigation. The system co-ordinates well with slatted floors and results not only in a considerable saving in labour, but also of litter.

Potatoes

Approximately 65% of the potato crop is grown for direct human consumption. Farmers must, therefore, be prepared to adopt harvesting and handling methods which will reduce mechanical damage to a minimum and provide the consumer with potatoes at a reasonable price. Existing methods for harvesting and handling often result in a high proportion of damaged tubers, reducing their keeping quality and saleability, especially for pre-packing. All unnecessary handling should be eliminated and necessary operations carried out in such a way that damage is kept to an absolute minimum.

Because of the present inability of complete potato harvesters to work satisfactorily in certain soil conditions, and also since a relatively small acreage is grown by a large proportion of producers, ways of mechanising hand picking methods would seem to be desirable. The most practical way of achieving this, at the present time, would seem to be the adoption of stillage handling. This is an adaptation of the pallet system common in industry and employs stillages holding approximately 5 – 7 cwts. The potatoes are gathered into baskets and then tipped into the stillages placed at convenient points along the stint. Work study can play an important part in this system by ascertaining the optimum length of stint and the spacing of the stillages. Stillage handling involves slightly more work on the part of the picker compared with tipping baskets directly into a trailer. Transport to the store is effected by front and rear-mounted pallet carriers attached to the tractor. A front-mounted hydraulic loader and rear-mounted buckrake may be adapted for this task. Work in Britain and Norway indicates that this method is suitable for distances up to about half-a-mile. For greater distances the stillages may be transported by trailer to the store, or the contents of the stillages may be tipped into a trailer for transport in bulk. Where complete potato harvesters are used to deliver into trailers running alongside, a comparatively low labour efficiency results and, when harvesting 50 acres at a rate of ¼ acre per hour, may involve approximately 200 extra man-hours in the field. To obviate this, a bulk tank can be fitted as an integral part of the machine, as on sugar beet harvesters, emptying into a stationary transport vehicle. This may be a step back as regards the objectives of materials handling, since it involves an extra operation. Nevertheless, tanks are being fitted on some Continental machines. Bulk transport vehicles, with a truncated self-emptying hopper embodying belt conveyor, are more suited to handling potatoes than are tipping trailers, as damage to tubers is reduced at loading and unloading. They are used in conjunction with indoor storage, the potatoes being delivered on to an elevator fitted with a swinging end extension to avoid soil coning in the heap. The height of the extension should be adjustable to limit the length of drop of the tubers, so reducing damage to a minimum. Emptying of bulk stores can be effected by placing a conveyor in the ventilating ducts, the use of hand forks, notorious for causing damage, being almost entirely eliminated. A system which may be employed where potatoes are stored adjacent to a pre-packing plant is by using a water flume. This not only provides a cheap means of transport over longer distances, but gives the tubers a preliminary cleaning before entering the washing plant.

Stillages can also be used in conjunction with complete harvesters, the potatoes being delivered from the harvester into a stillage or around ½ – 1 ton capacity carried on a trailer drawn alongside, or, to improve labour efficiency, mounting the stillage on the harvester. The former system is commonly employed in the United States, but may result in a high proportion of damaged tubers, unless baffles are fitted inside the stillage to break their fall. A stillage capacity of around 10 cwt. is about the optimum if a front-end tractor loader is used for handling, but with a fork lift attachment or a special fork lift truck a capacity of 15 cwt. to 1 ton may be possible.

Storage in stillages offers certain advantages when used in conjunction with this form of harvesting; damage is reduced to a minimum by the reduction of handling operations and less labour is required. The system offers distinct advantages where different varieties have to be kept separate and might be employed effectively in conjunction with a centralised store adjacent to a pre-packing station.

Stillage handling will usually involve rather less capital outlay and can probably be justified for quantities of up to 200 tons, but above this figure a bulk handling system may be justified. In both systems cost per ton may be reduced by employing the equipment for handling other farm produce—for example, grain and fertilisers.

Finally, if portable buildings, providing a cheap shelter, become a reality, might not outdoor clamps become a more common sight in our fields?

Conclusion

The Paper has dealt mainly with those enterprises which seem to offer the greatest scope for development in mechanical and bulk handling and which will probably take place in the foreseeable future. Bulk handling of fertilisers and feeding stuffs has not been dealt with, but also offers considerable possibilities.

In practically all farming enterprises mechanical handling is in its infancy, and future development will provide an interesting and exciting study in this field.

(III) MECHANICAL HANDLING ON HILL FARMS

by I. B. Warboys,* B.Sc. (Agric.).

Introduction

SINCE 50% of the labour in agriculture is concerned with the care of livestock, the mechanisation of livestock enterprises is a pressing problem. Much livestock tending is concerned with feeding and littering —that is, the distribution of materials. Thus the consideration of materials handling on hill farms is justified, since often feeding of stock occurs outside as well as within farm buildings. Although farm transport cannot be considered in isolation from the planning of materials handling and its integration into the farm as a whole, it is considered that the general problem of farm transport is of such importance in hill and upland areas as to warrant special attention, since it occupies a much higher percentage of tractor time than on lowland arable farms.

Conditions of transportation and the character and diversity of agricultural materials make the problem a complex one, and will vary from country to country and region to region. Since this is so, it will be necessary to define the background of the problem by referring briefly to the agricultural area to which this Paper relates— mainly the hill and upland areas of Wales. It is as well to point out that there are hill and upland areas elsewhere in the U.K.—for example, in Scotland, in the North and South-West of England—with similar transport problems and outside the United Kingdom in European countries, where conditions may be even more severe.[1]

Main Agricultural Features of Wales

Some 40% of the total land area is unimproved rough grazing, hill and moorland devoted to stock rearing, principally of sheep. Three-fifths of the land is above 500 ft., and one-quarter is above 1,000 ft. There are about 26,000 upland and hill farms—that is, just over half the number of agricultural holdings in Wales. The soils over much of the large upland area are shallow, rocky and deficient in lime and phosphates, except for the eastern area, the south-west, and in river valleys, where the soils are deeper and more fertile. Breconshire, for example, has 25% of tillage, but over 60% of its area is above 1,000 ft. The rainfall is generally high, ranging from 40 ins. on the coastal belt to over 80 ins. in areas of high relief—for example, Snowdonia. Grass is predominant in an area where steepness is a regular feature of topography.

Types of Farming

Although the typical hill farm is livestock rearing, there are many hill and upland areas where mixed and

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even dairy farms occur. A general agricultural problem is that of winter keep. Due to the development of dairying in lowland areas—for example, in Anglesey, the Lleyn Peninsula, and in Vale of Clwyd in the North, in the Vale of Glamorgan in the South, and in the coastal belt of West Wales—the livestock rearing farms have fewer areas in which to over-winter ewe lambs. Furthermore, due to the shortage of land between hill and lowland (the enclosed hill pasture, or " ffridd "), hill and upland farms cannot over-winter sufficient stock to exploit fully the flush of summer grass. There is scope, therefore, for improvement of hill pasture, and increased arable production based on sound rotations, to enable these farms to carry more stock through the winter.

Haulage Problem

As far as mechanisation is concerned, the Report of the Working Party on Machinery Requirements of Upland and Hill Farms in 1947 considered that the greatest problem was inter- and intra-farm haulage, and recommended that a tractor with four-wheel drive would fulfil the needs of the average hill farmer. The Welsh Hill Farm Mechanisation Survey[2] conducted by the N.I.A.E. in 1955–56 confirmed that the problem of haulage was common to most hill farms, and suggested that a p.t.o. driven trailer might be a more economic solution than a four-wheel drive tractor, since most farmers would be unwilling to pay the extra £100 or more for the latter. As will be mentioned later, it is considered that one important factor contributing to the problem of haulage is the use of unsuitable trailers—often home or locally made—for the modern all-purpose tractor. Haulage, therefore, in wet weather on loose-surfaced, rough roads and on wet slopes remains a problem.

Most developments in recent years in reducing labour through mechanisation have been on farm units on level land. There is considerable criticism by farmers of insufficient mechanisation of operations on sloping ground, especially tillage and haulage. Estimates and an economic survey[3] in Wales suggest that from 36–50% of the tractor's time is spent on haulage. It is therefore important to consider ways of improving the efficiency of transport, or of reducing its need altogether, and so contributing to a lowering of farm costs.

The Nature of Goods requiring Transport

Due to the variety of agricultural units and the diversity of enterprises, the number of agricultural goods requiring handling on Welsh farms is high. They include cereal grains and corn-in-the-sheaf, roots and roughages such as hay and silage, farmyard manure and artificial fertilisers, liquids such as liquid manure, milk, herbicides, and even water, and miscellaneous materials such as fencing posts, hurdles, etc. The more diverse the farming system the greater the problem, and it is not unusual to find all of the above products requiring transport at some time and to some place on a farm of under 100 acres ! However, on a typical livestock rearing farm the materials handled will be some roughage, perhaps a little fertiliser, fencing materials, etc., with the main transport problem being that of getting the farmer himself around the farm. With many mixed farms common to hill and upland areas, a large number of materials in small quantities are handled by hand where size of enterprise limits the use of specialist equipment.

The Nature of Roads and their Condition

The conditions under which transportation is carried out will affect the efficiency. This is particularly important in the case of agriculture, where transport often has to be conducted on tilled soil or on wet slopes or unbuilt roads. Speed is therefore low due to the unfavourable transport conditions, and also due to the peculiar properties of the goods. Load size, particularly in Wales, is restricted by narrow roads and gateways and sloping conditions. Thus at the present time of the total road mileage of 19,406 miles in Wales, there are 9,365 miles of unclassified and unadopted roads in poor condition, particularly in the winter, often very rutted, badly surfaced, making access to farms difficult and restricting movement within farms. Fortunately, due to Government financial assistance, conditions are gradually improving, and good work is being done by the Forestry Commission in making available to agriculture roads which they themselves require in plantations.[4]

Type of Transport

Transport can be manual, horse-drawn, tractor-drawn, and self-propelled. Much transport on the farm is conducted manually by use of buckets, sack barrows and trolleys. The latter require level concrete surfaces for efficient use, which are seldom found on hill and upland farms. Although tractor-drawn vehicles of the two-wheel type are in common use, not surprisingly in Wales many are converted horse carts, home-made or locally made. In the Welsh Hill Farm Mechanisation Survey on 60 hill and upland farms, 73 of the 84 trailers available were home or locally made, and only 11 made by manufacturers. Farmers considered that the manufacturer's trailers were too heavy and too costly. Consequently, a large percentage of transport available is not designed for the modern tractor, which requires high drawbar weight to perform adequately as a haulage vehicle. This, perhaps, may account for the retention of the horse in some areas for difficult haulage in the winter.

On livestock farms of a size where the use of a dung spreader is justified, its use—as shown by a survey of 21 farms in Carmarthen in 1955[5]—was restricted, due to the expensive outlay involved. Thus on the 21 farms, three owned spreaders, six borrowed their neighbours' spreaders, and 12 were non-users of spreaders. This is one piece of equipment which could be more usefully multi-purpose, and if suited to transport of roughage and fitted with a p.t.o. driven axle it could then take the place of the conventional farm trailer.

Of tractor-mounted equipment, the transport box is very useful on mixed farms where quantities of materials are small, although it is not always suitable for the transport of roughage. There may be scope for larger transport boxes, perhaps, semi-mounted for safe handling on sloping ground, which could be nearly as versatile as the modern tipping trailer. The buckrake has also proved to have more transport uses than those for which it was originally designed.

The remaining form of transport requiring consideration is that which is self-propelled. Vehicles at present employed are vans, pick-ups and the occasional lorry, all of which are mostly restricted to performance on good and occasionally on poor surfaces. The true cross-country four-wheel drive type vehicle has not been readily accepted. The bias against its use is mainly on account of its high capital and fuel costs, and the fact that it is not so comfortable for the wife to go shopping as, say, a modern small van or pick-up costing half the price ! Yet often the van, pick-up and even the motor car is expected to do farm work, picking up the odd stray sheep from rough farm roads. However, with an increasing number of cross-country four-wheel drive type vehicles becoming available on farms where transport conditions are difficult and the proportion of the time spent on transportation is high, there is a case for this specialist type of vehicle, particularly if the tillage operations, now requiring a conventional tractor, were eliminated or let out on contract. This would apply to many livestock rearing farms where small acreages are tilled for winter feed. Even if this is not acceptable, then there is scope for reduction in the size of mobile power units—say, a tractor of under 25 b.h.p. with simple hydraulics—since there is no justification for a £700 tractor to do the tillage work of a few acres of winter keep.

Methods of Reducing Need for Transport

As pointed out by Dilke,[6] handling or movement of a product adds to the cost, and therefore the primary rule shou.d be to eliminate or minimise handling. This is particularly applicable to many Welsh farms, where the distribution of roughages in winter, when transport conditions are severe, could be avoided by storage of such materials where they are required. Better use could be made of gravity, since many farm buildings are situated in positions where slope could be utilised. Unfortunately, in many cases the dimensions, layout and arrangements of buildings cause transport to be used unnecessarily, and labour to be used inefficiently when feeding cannot be conducted from outside the stock area. Undoubtedly, there is scope for extension of self-feeding to reduce the need for distribution.

The Role of Contractor Services, Machinery Syndicates and Scope for Sharing Equipment

On many livestock and mixed farms, where the number of different materials handled is large and their quantity small, there is little scope for the use of specialist equipment. It is of interest to examine materials in relation to possible division of handling between the farmer and contractor. The contractor would be able to exploit the technical advantages of the crawler and four-wheel drive tractor, as well as such specialist equipment as aircraft, lime guns and even hover craft. The following materials could be handled by a contractor: farmyard manure, liquid manure, artificial fertilisers, herbicides. In addition, the tillage and harvesting of cereals, roots and roughages could be carried out by contractors. In practice, this is gradually coming about, for much dung handling is now done by contractors or by the farmer borrowing his neighbour's equipment. Similarly, the handling of liquid manure and artificial fertilisers can be undertaken. Thus on the University College Farm at Aberystwyth all fertilisers this Spring have been applied by the suppliers with a two-ton bulk spreader, eliminating the need for storage and handling of sacks. Unfortunately, so far machinery syndicates have not developed as rapidly as expected, and there are only two operating at the present time in Wales, compared with the 200 or so in England.

The technical advantages of aircraft in hill areas could only be effective through contract services or machinery syndicates, since in hill areas, where economic margins are small, it is more difficult to finance specialist equipment. Unfortunately, due to heavy fertiliser dressings required, particularly of lime at the rate of 2 – 3 tons per acre, the scope of aerial farming is limited, but a contract service could well provide equipment for up-grading of pasture by herbicides, and distribution of fencing materials for enclosure of these improved areas. The Forestry Commission, who may have use for such specialist equipment in their plantation work, may be in a position to assist farmers.

It is realised that only one aspect of the problem of handling has been discussed very briefly with reference to the general problem of transport. This aspect of mechanisation cannot be considered in isolation, since transport is only part of the general plan of materials handling, even on the hill and upland farm. Some suggestions have been made as to ways in which the problem can be alleviated, and it is clear that there is no single solution. However, several interesting features emerge. Firstly, the reduction of enterprises on many mixed farms would lead to a simplication of the handling problem, and would reduce the amount of equipment now thought necessary or desirable on these farms. This would have an important repercussion, in that more working capital would be made available for purchase of extra livestock, or other inputs such as fertiliser, and so increase the size of business. Secondly, there is considerable scope for contract services, machinery syndicates, and sharing of specialist equipment. Finally, better attention to the siting of feeds and improvements in building layout will lead to a reduction in the need for distribution of materials under difficult haulage conditions.

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Summary

Haulage, although only part of mechanical handling, is considered to be a major problem on many hill and upland farms. It is considered with particular reference to Wales, where the present diverse nature of the farming accentuates it. The conditions fortrans portation and the equipment available on many farms is not considered to be altogether suitable. Various suggestions are made to overcome the problem in particular by simplifying and reducing enterprises and so reduce the number of materials requiring handling, and much more reliance on contract services, machinery syndicates, and sharing of machinery between farmers to take advantageof specialist equipment. Improvements in farm building layout and design could reduce the need for transport altogether under difficult conditions.

DISCUSSION

MR. H. G. PRYOR (Essex) started off by saying that, in opening the discussion on those three excellent Papers, he felt that a few comments on the broader aspects of mechanical handling were called for first. Mechanical handling anywhere really fell into two categories—continuous flow and movement in batches. Until a few years ago, Mr. Pryor had been a keen disciple of continuous flow methods. But practical experience and the decline in the labour force had converted him more and more towards the batch method, the chief advantage being the elimination of synchronised operations. This country's difficult climate and varying soil conditions made it essential for every man to be able to carry out his task without being affected by the performance of any other operator or machine. In addition, one-man operations were much easier to supervise and control ; the administrative time thus saved could be utilised to obtain greater efficiency or to relax, whichever was the more important.

A further important point on general handling had been brought out by Mr. Warboys in his quotation of Dilke, who emphasised that any movement of a product cost money. That, of course, included emptying or filling containers, whether they were trailers, fork-lift buckets, barrows or bags, and so on. This rule particularly applied to the subject of Mr. Calverley's Paper, " Milling and Mixing on the Farm." It was most important that all ingredients that were used at a rate of more than a ton per week should be bought and stored in bulk, and not man-handled at any time.

Mr. Calverley, Mr. Pryor reminded the audience, had discussed the problem of milling oats. As oats, however, were becoming less economic to grow, the problem would probably diminish constantly in the future. A point that had not been mentioned by Mr. Calverley was the possibility of cooking rather than grinding grain. Experiments had suggested that it could be possible to cook grain for about 15s. per ton, using night rate electricity. No doubt, this method of preparing feed would attract a lot of attention during the next few years. In the course of his discussion on mixers, Mr. Calverley had said that horizontal mixers were effective in about a fifth of the time required by other types. This being so, Mr. Pryor asked why they were not more popular.

While on this subject of mixing, he said that, since there must be many farms on which it was not possible to site the mixing plant near the point of consumption, there might be a case for a mobile power take-off drive mixer-transporter capable of elevating its batch into a storage bin.

Mr. Howe had opened his Paper with some very sound observations on general handling. After commenting on the easier materials, such as grain and milk, Mr. Howe had dealt at greater length with the really tricky problems of hay, silage and potatoes. There could be no doubt, Mr. Pryor continued, that a perfect system of making and handling hay could benefit more farmers than any other development in the mechanisation of agriculture. There appeared to be three possibilities : The first was to bale in the field, where the bale thrower offered the only complete system of mechanical handling. Owing to the difficulties of this country's climate, some form of artificial drying would probably be considered necessary, and the disadvantage of field baling was that there could be no worse way of promoting air circulationt rhough hay. However that might be, it was a better method than leaving bales in heaps uncovered in the fields where the chances of deterioration were nine times greater than the possibility of improvement.

The second method was the storage drying of loose hay. That system was probably the correct one, but to facilitate mechanical handling and distribution in the store, chopping was necessary. Mr. Pryor, for one, was hoping that those very good scientists at Silsoe would be able to give them some guidance on that problem before long.

The third method—a very new one—was hay wafering to facilitate handling. That system might well be linked with loose collection and barn drying.

But whichever method was finally accepted must be designed to work in the wet seasons. It just was not good enough to operate only in average conditions. It was probable that, if a really satisfactory system of making and handling hay could be found, silage making would decline rapidly. No farmer liked moving two tons of water with every ton of feed, and the capital cost of machines to make silage mechanically was probably £1,500. Mr. Howe had suggested that American farmers mechanised to eliminate labour rather than to obtain a return on capital. Mr. Pryor suggested that British farmers should prepare for that outlook in 10 years' time.

The next product dealt with by Mr. Howe had been potatoes. That crop introduced the factor of damage-avoidance to that discussion. Mr. Pryor had been particularly pleased to hear Mr. Howe discuss stillage handling. It certainly offered the simplest way of avoiding damage. The flexibility of the system, together with the safety and simplicity of storage in stillage, meant that this method of handling was going to command a great deal of attention in the future. A further point was that the capital cost per ton was fairly constant down to quite small tonnages. He congratulated Mr. Howe on pointing out that potato harvesters often resulted in a low labour efficiency. The importance of regular labour requirement was often overlooked when the value of potato harvesters was being assessed. The answer, as Mr. Howe had rightly pointed out, was to carry the crop to the ends of the field on the harvester. Mr. Pryor said that at least one machine would make its appearance this year which would carry the potatoes either in stillages or in bags on flat pallets to the headlands.

In discussing handling in a bulk store, Mr. Howe had said that a conveyor could be placed in the duct for unloading ; but Mr. Pryor argued that, as the angle of repose of stored potatoes was between 60 and 90 degrees, he imagined that a considerable percentage would have to be moved with the vicious hand fork.

Turning to Mr. Warboys' Paper, Mr. Pryor said that he had won their sympathy for the farmers who had to cope with those special problems on hill farms. One could only ask whether it was possible to liquefy more of the commodities and handle them with a pump. In the transport department, the automatic hitch and semi-imposed trailer must have been a great help where applied, and certainly the multi-purpose muck spreader and moving-floor trailer should prove very useful. Unfortunately, Mr. Pryor remarked, it was not possible to speed the floor enough on the majority of machines, and its efficiency as a self-unloading trailer was consequently severely curtailed. Finally, Mr. Warboys had made the most important point that the number of enterprises conducted by the individual farmer must be severely reduced. Mr. Pryor declared that one might be forgiven for the observation that, like God, the engineer could only help those who helped themselves.

MR. CALVERLEY, after thanking Mr. Pryor for his remarks, said that he had kept clear of the subject of cooking feed. He thought that more was needed to be known about it. In the Paper he had mentioned £400 as the cost of putting in a cuber. Mr. Calverley asked what would be the cost of the machinery if it had got to deal with the feed further.

He said that he had already been taken to task on his comparison of horizontal and vertical mixers. The results had been taken from a comparison on hand and vertical mixing several years ago. To achieve the same standard of mixing, these results indicated that the time would be 15 min. for vertical and 5 min. for horizontal mixing. But it should be seen nowadays that these times for vertical mixing might be reduced.

On a mixer-transporter, he said that it might have a specific application, but not a general one. If one had that amount of material to move, one would be on to a big system and there might be a danger of over-mechanising. It had got to be kept simple.

MR. HOWE had two comments on Mr. Pryor's statements about hay. There was one method not mentioned by Mr. Pryor—making hay with a forage-harvester. That way there was high moisture extraction, and by picking up the material with the forage-harvester and storing it loose, much density might well be got rid of. It was possible also to eliminate a lot of manual labour. The figures Mr. Howe had read about potatoes and moving them from the store had been that 85 per cent. of the potatoes could be removed by putting conveyors in the ducts. But if these conveyors were put below the ducts a greater quantity could be removed. One thing Mr. Howe had not mentioned in reading the Paper was that in Belgium they are using water flumes below the ducts, and this could give preliminary washing to the tubers.

MR. WARBOYS replied to Mr. Pryor's point about moving materials as liquids. It certainly applied to manure and slats were going to come in. He thought that a large number of the farms he had been talking about could simplify their enterprises. Many were trying to grow crops for winter keep in conditions which were unrealistic, whereas if they were prepared to buy some feed in, it would certainly help.

MR. J. H. COCK (East Anglian Real Property Co.) inquired whether there was a quick, cheap metering device to put into a farm grain system, so that inputs and outputs could be accurately measured.

MR. CALVERLEY answered that one firm had recently produced a small unit which was quite accurate enough and would do the job.

MR. U. G. CURSON (Norwich) addressed his remarks to Mr. Howe, and referred to the comment that tower silos were " status symbols." Mr. Curson could not agree when there were silos on the market which could be bought for about the same price as the pit silo and covered accommodation. He pointed out the difficulties of making silage and the danger of advising farmers to make silage if they did not get complete compaction. The process should not be over-simplified.

MR. B. CORNELIUS (Massey-Ferguson, Ltd.) asked Mr. Warboys how long the " Brother John," to whom Mr. Warboys had referred in reading his Paper, would be allowed by the economic situation to push his wheelbarrow over the Welsh hill farms.

MR. WARBOYS agreed that people of that type were bound to be squeezed out eventually. But the real family farm was going to exist for some time to come because their standard of living was not what people in England expected.

MR. R. M. CHAMBERS (Warwicks.) wanted to know how much difficulty would be experienced by Welsh farmers if they realised that the transport mechanisms were limited to 15 sq. ft. at the rear and 8 sq. ft. at the front of the tractor.

MR. WARBOYS said that he had inquired about that. Of course, some farmers were carrying things on the buckrake.

MR. CHAMBERS responded that that was only because the police were winking at it.

MR. PRIEST wound up this part of the conference by saying how grateful they were to Messrs. Calverley, Howe and Warboys for the Papers in the trilogy.

THE USES OF PLASTICS IN AGRICULTURE

by A. N. HOLMES,* M.A. (Cantab.).

Introduction

IF one includes rubber and bitumen, the origin of plastics is lost in antiquity. However, the plastics industry as we know it to-day has resulted from developments, most of which have taken place in the last three decades. Apart from the thermosetting resins, our experience of plastics before 1930 was confined almost solely to polystyrene. After a lengthy induction period, one discovery followed another in the 1930's, until to-day we have a wide range of materials fulfilling requirements ranging from packaging to engineering.

While the thermosetting resins, such as phenol formaldehyde, urea formaldehyde and alkyds have progressed steadily, the growth of the thermoplastics industry has been by comparison explosive. Compared with the chemical industry as a whole, which has been expanding at the rate of 5% per annum, thermoplastics have grown at an average rate of 15% to 20% per annum. The following table gives a comparison of the rates of growth of a range of thermoplastics and thermosetting resins :

Table I

TABLE INDICATING GROWTH OF RESINS AND PLASTICS

Product	1957	1958	*Sales, U.S.A.* × 10^3 *lb.* 1959	1960	1961	*Average Annual Growth Rate*
Total Polyethylene	662,000	855,000	1,116,000	1,195,000	1,515,000	23%
High-density Polyethylene				171,000	264,500	54%
Polypropylene				35,000	70,000	100%
P.V.C. and Related Copolymers	635,000	649,000	874,000	904,000	950,000	10·6%
Polystyrene	647,000	724,000	919,000	980,000	1,072,000	13·6%
Celluloses	136,200	133,100	149,624	138,840	145,200	1·6%
Polycarbonates				500	1,700	240%
Phenolics†	532,000	488,000	633,000	665,000	668,000	5·9%
Reinforced Plastics			264,000	255,100	258,560	−0·9%
Urea and Melamine		326,000	386,500	363,000	374,000	4·6%

† Production figures are given rather than sales, since a large part of the industry is captive and production figures are thought to be more truly indicative of actual consumption.

While there are several fields in which thermoplastics impinge on the agricultural industry, the overall impression is that generally the agricultural industry can get along quite nicely without being too concerned about developments in the plastics field. I think it would be interesting to spend some time looking at this statement. Is it true and, if so, to what extent can the agricultural and plastics industry examine each other's activities to their mutual benefit ?

I am proposing, therefore, to tell you something about the most important thermoplastics available to-day—a little about their properties and the major outlets into which they are sold at present.

APPLICATIONS FOR PLASTICS TO-DAY

We have already seen that the major and fast-growing thermoplastics are the various forms of polyethylene, p.v.c. and polystyrene, with the newer materials such as polypropylene coming up fast. It can be seen from the next table (Table II) that one of the major outlets for thermoplastics lies in the field of packaging (a table to show the major outlets for low-density polyethylene, high-density polyethylene, polypropylene, polystyrene and p.v.c.).

Most of the injection moulded articles, bottles and film, ultimately finish up as containers for liquid or solids, or protective wrappers for packaging of one kind

Table II

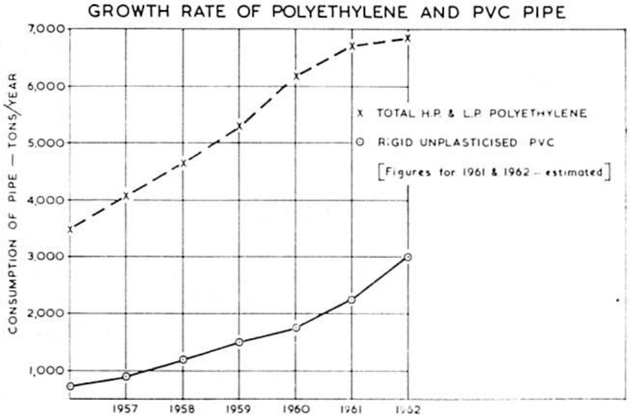
MAJOR OUTLETS FOR THERMOPLASTICS

(Expressed as a percentage of the total U.K. market for each product)

	High-density Polyethylene	*Low-density Polyethylene*	*Polypropylene*	*Polystyrene* *Expanded*	*Polystyrene* *Non-Expanded*	*P.V.C.*
Packaging	10·5	41·5	6	8·5	23·5	5
Consumer Durables	47·5	20	80	—	15·5	20
Piping	10	8·5	5	—	—	6
Electrical	5	16·5	—	—	13	20
Refrigerators	—	—	—	63	23	—
Building	—	—	—	24	2	15
Miscellaneous	27	13·5	9	4·5	23	34

* General Manager, Plastics and Rubbers Division, Shell Chemical Co., Ltd.

or another. There is also a rapidly growing market for expanded polystyrene and polyurethane foams, particularly for insulation of refrigerated stores. Polyethylene and p.v.c. are now being sold in large tonnages for coating of wires and cables which are used in the electrical and telephone industry. Plastic pipes for transport of liquids and general rain-water goods represent a growing outlet.



In the utilisation of plastics for these purposes they were, in the early days, often seriously misapplied in the uses to which they were put and the way in which moulds for them were designed. Generally, design was along the lines of a straight replacement of conventional materials, without any attention being paid to the necessity for shaping the material to the application.

This early immaturity had a very damaging effect on the acceptance of thermoplastics, but during the last two decades tremendous strides have been made both in appreciation of what the material will do and in design of new methods of fabrication. As a result of this experience, the use of plastics can achieve some of the following :

(*a*) They do the job better.
(*b*) They are cheaper.
(*c*) They are more attractive in appearance.
(*d*) They bring about overall reductions in cost and labour.
(*e*) They are in most cases lighter than the materials they replace.

I should like to turn now to specific fields of application which will serve to illustrate the properties and rapidly advancing techniques that are now available from the wide range of thermoplastics on the market to-day.

1. Injection Moulding

The primary requirements in this field are for strong, tough materials which can be moulded at high speed to allow an overall rapid rate of production. This field is becoming increasingly sophisticated, with grades of material individually designed for specific end uses. For example, there are some 200 injection moulding grades of polystyrene on the U.K. market at the present time. These are designed for applications ranging from very thin-walled containers for Yoghurt to large crates for handling beer and milk. Moulded piece parts for tractors and electrical equipment are also other typical examples.

2. Extrusion

The main outlet for material in the extrusion field lies in the manufacture of film, especially polyolefin film. When low-density polyethylene was first developed, one of its main applications was in the cable insulation field, but 30% of world production of polyethylene is now for film. Nearly all this film finds its way into packaging applications of one sort or another.

3. Blow Moulding

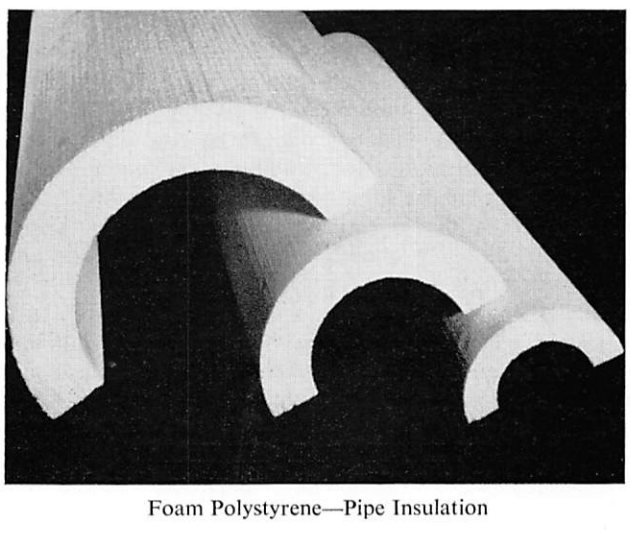
This is essentially an extrusion process, but the technique of blow moulding has developed so much in recent years that it is now rapidly becoming a technology in its own right. Until recently, blow moulding was developed on a modest scale, aimed at the production of bottles and containers of a similar simple shape. However, the technique has developed so rapidly that 90-gallon containers and over are now being contemplated. Blow moulding lends itself to the manufacture of intricate shapes, and work is in hand on a blow moulded refrigerator inner where the liner and door lining are blown in a single piece, subsequently they are separated by hot wire cutting.

4. Powder Techniques

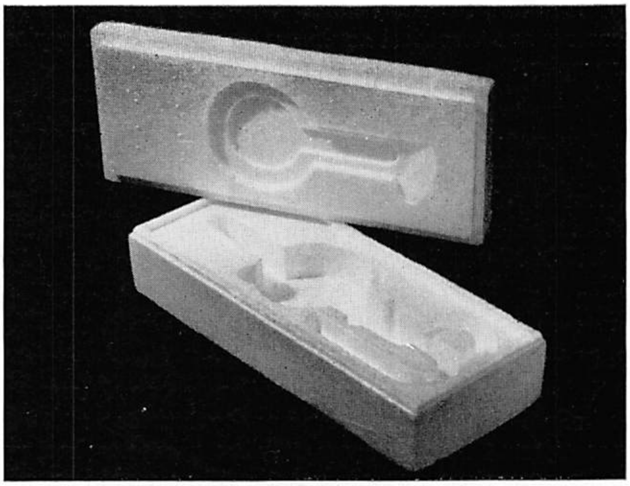
The development of the Engel process will extend even further the size of container that can be economically fabricated. This process allows for construction of large hollow moulds from inexpensive metal sheet. These moulds are heated so that when plastic powder is put inside them it melts and adheres to the wall, thus forming a skin of uniform thickness. Because of low mould costs, it is anticipated that this usage will expand rapidly, especially if the thermoplastics can be combined with reinforcing materials such as glass fibre.

5. Moulding of Expandable Material

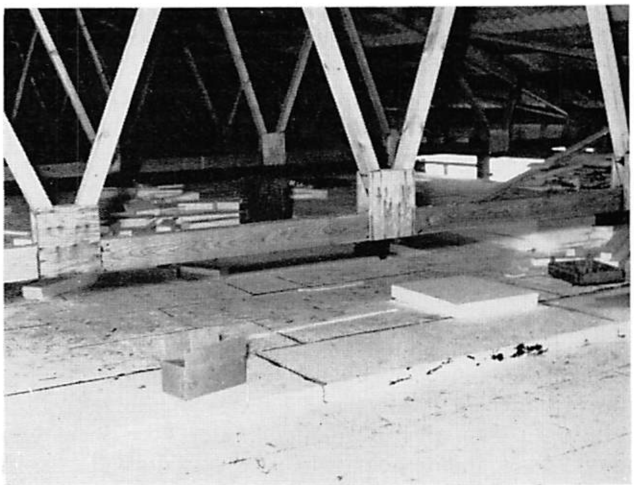
The war-time development by B.A.S.F. of expandable polystyrene has led to a completely new industry, which has expanded very rapidly in Germany and the U.S.A. and is now on the threshold of a very rapid rise in the



Foam Polystyrene—Pipe Insulation



Foamed Polystyrene—Shock-proof Package.



Foamed Polystyrene—Roof Insulation of a Fruit Store.

U.K. Expandable polystyrene consists of beads about 1 mm. in diameter, in which is incorporated a low boiling hydrocarbon liquid. On mixing with low-pressure steam, these beads expand thirty times in volume and, when finally moulded, have a density 1/60th of that of the basic polystyrene. Initially, the main outlet for this material was for thermal insulation, but it is now finding increasing application for sound insulation in buildings and as a protective material in the packaging field. The latter is the most recent development, and as new and more rapid techniques for moulding get under way, it will probably be the most rapidly growing outlet. The advantages of the material lie in its cheapness (since volumetrically it is mainly air), shock resistance and attractive appearance. Now that I have described very briefly the types of processes which are used for fabricating plastics, I will try to show how these materials and these techniques are applicable to the agricultural and horticultural industry.

AGRICULTURAL INDUSTRY

As it is difficult to divide the agricultural/horticultural industry into definitive sections, I propose to discuss the application of plastics throughout the industry on the basis of the particular advantage which is realised.

Broadly, as I see it, there are several main reasons why plastics should be used in the farming industry. These are :

1. Plastics permit appreciable labour saving.
2. Plastics reduce product or raw material spoilage.
3. Plastics increase producivity or quality of goods.
4. Plastics save money.

I would like to consider the four headings detailed above individually, and I will highlight some of the particular applications which are of greatest interest. I hope also to give an indication of future potential developments under the appropriate headings :

1. Plastics Permit Appreciable Labour Saving

It is well known that in the less-advanced farming communities, such as India, one man will produce food for between two and four people, whereas in the more advanced countries, such as the U.K., one man normally produces food for 14 people. This fact depicts the importance of the application of technology generally to farming, and plastics are already playing their part in getting a higher yield of food for equal labour.

The handling and storage of fertiliser bags in the average farm, to quote one example where labour saving can be effected by using plastics, presents some difficulty. Normally, with paper sacks dry storage conditions are essential if the product is to be preserved in good condition. Recent trends in the U.S.A., and to some extent in Holland, in Germany, and to a smaller extent in this country, show that polyethylene bags produced at roughly the same cost as the conventional sack enable handling operations to be substantially reduced. In the first place, the sack can be delivered on to the field where it is to be used, and no deterioration of the contents will occur, irrespective of the weather conditions existing on the open field. (Normally using paper sacks, the fertiliser is first placed in a dry barn, and then at the appropriate time it is shifted to the field. Clearly, by the use of plastics one complete handling operation is eliminated.) Secondly, because of the excellent chemical resistance of the polyethylene sack, these packages will have an indefinite life and will not " rot " after a period of, say, 18 months when in contact with certain fertiliser concentrates (as occurs with paper).

Since the use of chemical fertilisers has become popular, corrosion problems on the farm have been encountered with growing severity. This corrosion has resulted in a considerable waste of man-power involved in cleaning and maintenance of equipment, and to overcome this difficulty, plastics either in the moulded form or deposited from suitable solvents are now used in a wide variety of applications where hitherto corrosion of metals was troublesome. A number of typical examples are :

(*a*) Epoxide-coated fertiliser distributors.
(*b*) Sterilisable plastic dairy equipment.
(*c*) Plastic jets for spray equipment.
(*d*) Epoxide-surfaced cowshed floors.

Another example of where labour economies have been made is in the pipe field. In the past the use of pipes made from conventional materials for water service installation, irrigation and drainage has resulted in considerable labour being used for the installation of these facilities. Because plastic is lighter—in many cases as cheap as—the conventional material, there is a growing trend for plastics to become the preferred article. In particular, for water service application, coilable polyethylene pipe usually " mole-ploughed " from a coil carried on the back of a tractor now has virtually replaced the older type of galvanised zinc piping, and because of its infinite longevity is clearly the preferred material. It seems as if the trend which has been established for water service installation will also be repeated in farm drainage, and plastics should replace conventional materials. Here rigid p.v.c. pipe made with slots spaced longitudinally is replacing the conventional clay drain in Holland at an increasing rate every year. It is worthwhile recording that by the use of p.v.c. pipe the " gang " operating the drainage machine can be reduced from nine men to six men, and this saving in man-power is attributed solely to the lightness of the plastic pipe and consequent ease of transport. A further interesting development in drainage is where a reel of plastic is carried at the back of a tractor equipped essentially with a moling device. After the film from the reel has been fed into the mole, the two sides are joined by a zip-like mechanism. By the use of this method of drainage, installation costs are approximately halved.

2. Plastics Reduce Product or Raw Material Spoilage

In industrialised countries where considerable transport of food is necessary in order for it to reach the main centres of population appreciable losses and spoilage during transport are likely to occur unless proper packaging arrangements are made. Probably one of the most successful applications of plastics has been in the field of produce packaging, where probably one-third of the film produced in this country is currently absorbed. Polyethylene films for banana packaging and polyethylene film for potato packaging are, of course, well-known examples, and in the latter case it is worth recording that about 40% of the potatoes packaged in this country are sold in polyethylene bags.

Although the growth of the pre-packing of potatoes can be attributed largely to the reduction in material spoilage, there are numerous other advantages on which I would like to digress for a moment. These include better sales appeal, ability to offer more consistent and cleaner products, and the intrinsic suitability of the pack for super-market presentation. Better sales appeal and quicker service, with consequent higher turnover, means that retail margins can be reduced. This in turn means that frequently the increased cost due to the packaging operation can be effectively diminished. The suitability of pre-packaged vegetables for the super market is obvious, but this method of packaging has also been of considerable interest to the farmer.

On the old system of distribution of produce, where products were sent to a central fruit market and frequently when bought by the wholesaler returned to the production area for re-sale, the price was often higher than necessary due to the number of handling operations. For pre-packaged goods, individual farmers or packing stations can advantageously perform the packaging operation close to the primary product. These stations can then sell direct to the retailer by the shortest route without going through the intervening steps of central market distribution nad thus lower the cost of the operation.

Another interesting application where plastic film has improved farming processes is in the case of silage preparation, where by the use of polyethylene film a better-quality silage can be produced in the open. Normally, if silage is exposed to weather conditions decay and loss of nutrient value frequently occurs. Other examples where plastic film (mainly polyethylene film) can be used advantageously to prevent deterioration of crops include mulching, cloche fabrication and protection of stacks and Dutch barns.

3. Plastics Increase Productivity

In the greenhouse industry it is common to obtain a rough degree of insulation by putting a layer of polyethylene film on the inside of the glass greenhouse. This results in the average temperature of the house being significantly higher for equivalent heating, giving rise to increased productivity of the crop in question.

As far as greenhouse applications are concerned, it would seem logical to use a plastic film only and eliminate the conventional glass. This aspect has, however, received considerable attention, but it has not yet been found possible to produce a film which is at the same time sufficiently rigid and sufficiently stable to degradation by ultra-violet light at an economic price. There has been some progress in this direction, however, and polyvinyl chloride compositions or polyethylene compositions stabilised to withstand prolonged exposure are now offered on the market. For my part, at this stage I believe that glass will remain the favoured material in this industry for a long time, but, nevertheless, it is worth quoting the following example in favour of temporary polyethylene sheet for glasshouse use :

The initial cost of covering a greenhouse with 2 – 4 mil. film is about one-quarter to one-tenth the equivalent cost for a comparable article in glass.

It has been estimated that the average annual cost of film replacement is less than the annual cost of cleaning glass on a conventional greenhouse. I would say that, for large greenhouses, film replacement is a complex and therefore more expensive operation.

Much attention has been given to the use of black polyethylene film as a mulching material for use with strawberries and here the polyethylene film prevents the crop from becoming soiled and also, because it is black, ensures that the soil is maintained at a slightly higher temperature than ambient because of absorption of solar energy.

A practical trial comparing strawberries grown under normal conditions—*i.e.*, use of straw, etc.—and under black polyethylene mulch has provided the following results :

CROP (lb./Plant)

	Rival		*Prize-winner*	
Variety	*Polyethylene*	*Straw*	*Polyethylene*	*Straw*
Large berries ..	0.94	0·85	0·53	0·34
Medium berries ..	0·73	0·42	0·52	0·56
Small berries ..	0·18	0·08	0·31	0·32
	1·85	1·35	1·36	1·22

The yield from the mulched plants (which were themselves larger and leafier) is noticeably higher than from the straw process (a 50% increase has been claimed in the U.S.A.). No difference in crop timing was noted, although it might be expected that the mulched crop would ripen earlier. The extra cost of the film was compensated by the fact that no normal cultivation was necessary. Quoting figures obtained during a Shell trial, the total cost of mulching under black polyethylene worked out at £71/acre/annum. For straw the equivalent cost was £86/acre/annum, inclusive of weeding, cultivation and the cost of straw and strawing down.

A recent development in mulching has been the use of a double film layer (black underneath, which is covered with a thin layer of loose earth and over which is laid a thin layer of clear film). Tests on six vegetables show the use of double film produces markedly superior yields than black polyethylene alone. The increased yield was attributed to an earlier warming of the soil in spring and moderation of hot weather temperature. The explanation for this effect lies with the different physical characteristics of black and clear films. Black absorbs more heat from the sun in the daytime, but loses heat faster at night than clear film. Thus when the sun is shining, the clear film allows the warmth of the sun to pass through and be absorbed by the black film, which transmits heat to the soil. At night, however, when black film would normally lose its heat rapidly to the atmosphere, the clear film has trapped an insulating layer of air, which holds the soil heat, thus speeding germination and growth.

Thermal insulation of farm buildings achievable with a foamed polystyrene is desirable, since besides giving saving in fuel bills it permits control of the environment in the building. This is particularly important in piggeries, hatcheries and refrigerated gas stores for fruit, where constant temperature conditions favour improved and consistent products.

A word of warning should be given about possible adverse effects of excessive thermal insulation. The effect of expanded polystyrene insulation on the temperature of the building can be considerable, and, in the case of buildings housing livestock, steps should be taken to ensure an adequate supply of fresh air.

Foamed p.v.c. mattresses for cows seems an unlikely application. It is, however, a fact that the cows seem to be more satisfied and give significantly higher yields of milk, while at the same time labour charges incurred in straw removal and replacement are substantially reduced.

4. Plastic Saves Money

In all the previous cases positive advantages have resulted in plastics being used to replace conventional materials, and clearly either directly or indirectly money is saved as the result of the advantages incurred. By the following two examples I hope to emphasise the degree of saving which can be obtained by the use of plastics rather than conventional materials.

Example One—Land Drainage

It has been estimated by the National Institute of Agricultural Engineering that an approximate comparison of U.K. costs between conventional clay drains and of p.v.c. foil would be as follows :

TILE DRAINS

	£	s.	d.
Tiles..	1	7	0
Trenching Operations	1	0	0
Labour, Distribution and Laying Pipes..	1	5	0
Porous Backfill	2	5	0
Backfilling	0	3	0
Cost per Chain ..	£6	0	0

PLASTIC FOIL DRAINS

	£	s.	d.
P.V.C. Foil..	1	10	0
Laying	0	10	0
Jointing		12	0
Cost per Chain ..	£2	12	0

Example Two—Mains Water Service

For large service mains of the order of 3 in. i.d., a saving of approximately 2s. 5d. per yard on the total cost of the installed pipe can be achieved by the use of medium impact rigid p.v.c. pipe rather than spun iron pipe with wrapped–screwed gland joints. The chief savings here are in the labour and plant costs, where the lightness and ease of jointing of the plastic pipe are particularly important.

Where water service facilities are required on the farm for drinking troughs and similar jobs, very appreciable cost savings can be made by mole ploughing—say, a ¾ in. or 1 in. polyethylene pipe into the soil from a coil carried on the tractor—in preference to using conventional materials. As ½ in. and 1 in. polyethylene pipe (capable of withstanding requisite pressures) costs no more per foot length than steel pipe of a comparable diameter, it is clear that in an installation using " moled in " polyethylene pipe the cost saving is equivalent to money which otherwise would have been spent on ditching and pipe joining.

At this stage, it is well to mention that there are many possible uses for plastic which could be tried immediately, but unless there is some positive economic advantage in their use, it is unlikely that any appreciable penetration will be made. I would like now to mention certain speculative projects and to highlight some of those end uses which have already been noted, where I am confident that a big increase in the use of plastics will occur. These are necessarily my own feelings on the subject and can be regarded purely as " crystal gazing," but I hope that they will stimulate you into encouraging the use of plastics into a variety of suitable fields.

In the near future I envisage that plastics will have largely replaced conventional materials in the field of drainage, and fertiliser sacks. These applications have been discussed in detail previously, but I think that the tonnage for this country alone will probably exceed 15,000 tons by 1965 (say, 5,000 drainage and 10,000 polyethylene sacks).

In other fields, particularly for produce packaging, I envisage that formed plastic products will become widely accepted for egg, tomato and milk packaging. The reason for this generalised statement is that the present conventional materials are frequently deficient in physical properties, particularly when wet, or alternatively in the case of the packaging of items such as milk, conventional materials—*e.g.*, glass—leave much to be desired from a breakage and weight viewpoint.

A development receiving attention in the U.S.A. is the encapsulation of fertilisers in porous plastic in bead or pellet form. Here the plastic permits a slow issue of the fertiliser to the soil in solution form, and consequently a greater staying power of the fertiliser is achieved. Much work has yet to be done to get an economically acceptable process, but by foaming techniques the target should not be too far away.

There is much development work for plastic products which can be done in the field of irrigation. Firstly, where high-pressure coilable pipes are required, glass filament filled extruded thermoplastic pipes, such as are used for fire hoses in France, are likely to be adopted when economics become more favourable. Also there is now a process for the manufacture of porous plastic pipe from the cheaper thermoplastics, and these should be of interest for the irrigation of dry areas, as this porous pipe should be capable of being supplied in continuous coils for easy laying.

DISCUSSION

MR. J. EVANS (Ford Motor Co., Ltd.) said that plastic applications were accepted as a matter of course, particularly in household items, where their functional and cost advantages were well apparent. From the examples of plastic products they had seen that day, it was evident that not only the galvanised bucket had been supplanted, but also the galvanised iron roofing material.

He knew all would agree that Mr. Holmes had given them a most interesting insight to the ways in which plastics have been applied and how rewarding they were for the agricultural industry. The broad field he had ably covered indicated the scope of development yet to be undertaken, and in fact it must be a problem for Mr. Holmes to decide which avenue should be investigated and developed. Mr. Evans had, he said, been impressed with the plastic foil drains that had been shown, particularly the novel method of fastening sections. But he wondered if any collapse of the tubes occurred because of soil packing. As Mr. Holmes had said, the term plastics embraced a wide range of materials which were ever being extended to broaden still further the field of applications.

Mr. Evans said that the tractor of to-day had taken plastic developments largely proven on cars. For example, the seat cushion was found to be a p.v.c. covering that was edged with p.v.c. extruded piping to the preferred colour. That combination had proved very durable for a part which was subject to arduous wear and tear. The latest development of that was a specially-moulded foam rubber and p.v.c. skin (about 0·04 in. thick) which had the advantage of being permanently fixed to the seat pan with a synthetic adhesive, thereby eliminating the deterioration that could occur through moisture being present between the pan and cushion.

Nylon drive gears for proofmeters, speedometers, and so on, were, he claimed, quieter and cheaper than their steel counterparts. Nylon bearing bushes in control systems, and steering joints, eliminated the need for greasing. Other plastic parts were lamp lenses, battery trays, venting plugs, control taps and knobs, wiring covering, battery cables and control cables, covers, moulded p.v.c. dust extruders, and so on, their materials varying from hard diakon to polystyrene.

There was no doubt, however, that plastic's resistance to corrosion was one of its greatest attractoins to the agricultural engineer, and, if for no other reason, the complementation of plastics with metals and other materials would mean better products. For example, the development of an asbestos-filled phenolic material for the battery tray and covers obviated the corrosion usually experienced in service. The use of a cellulose acetate butyrate moulding for the glass sediment bowl of the fuel filter gave the advantage of being less brittle and, therefore, less liable to succumb to the hazards of vibration and external damage prevalent with tractors. Nylon fuel lines, again, were more durable than their steel counterparts and easier to assemble on the tractor.

Another welcome development mentioned by Mr. Evans was the marketing of a centrifugal pump for handling chemicals and corrosive liquids. The conventional phosphor-bronze castings and impellers all too soon gave trouble with these liquids, he said, but with the two half-housings and impeller in plastic, and graphited plastic face bearings mating with stainless steel thrust washers on the impeller, a more durable product resulted. The corrosion of implements, the current bugbear of farmers, could be similarly prevented by the intelligent application of plastics. Mr. Holmes had mentioned the spray nozzles and referred to fertiliser equipment, but plastic pulleys and gears in spreaders and other implements would undoubtedly improve the durability of that type of equipment.

Mention must also be made, he went on, of the use of transparent plastic models that help engineers on research and development, demonstration and service models, and also were indispensible for photo-electric stress analysis, enabling the speedy identification of local stress areas in complex parts.

As the tractor was vulnerable to corrosion, having to spend the greater part of its working life outdoors in all weathers, Mr. Evans asked Mr. Holmes to give an opinion as to whether he considered that tractors of the futuie would be having items like the current sheet-metal hood panels, radiator shell, chaff grilles, fenders, etc., in, say, polypropolene material and joined with synthetic adhesives to form durable, rattle-free panels in colours that would not fade.

It was Mr. Evan's belief that the current types of cab tended to be sound-boxes. Although some incorporated glass fibre panels to reduce transmission noises, it would appear that polypropolene panels could effectively be incorporated in future versions of tractor cabs. He thought Mr. Holmes might like to comment on this also.

MR. HOLMES started his reply by saying that in so far as Mr. Evans' question was about tractor design, he thought it was without doubt that they did have an absolute confidence that they would get much farther into what he would like to call automotive design than so far. He could not dwell too much on this, but it was very much in his company's own mind. He thought there was much scope in some of the particular possibilities Mr. Evans had mentioned, although, perhaps, not in the actual materials he had mentioned.

Mr. Holmes said a tremendous load could be put on plastic piping ; it varied according to the land, but at between 2 ft. and 1 ft. depth it was even possible to drive a tractor and such like over the top of the drain, and whatever effect resulted, the pipe would revert to its previous shape afterwards.

He said he had discovered that inside the trench, when putting in drains, gravel was included. It was his hope that he could even replace that gravel as well. Whether he could and whether at a price which was reasonable remained to be seen. But it was possible that the pipe might be surrounded with pieces of chopped-up plastic.

MR. MAGGS (Beds.) referred to previous remarks of Mr. Holmes that rats had attacked some plastic pipe that he had laid down. Mr. Maggs corroborated this, saying that in Bedfordshire their rats were certainly very partial to plastic pipes. His concern had extended a line in connection with a cowshed and rats had attacked pipe which was unpainted. This was possibly because the unpainted sections were more secluded. But they had replaced the pipe and tarred it, and had never had any trouble since. He also mentioned difficulty that had been experienced when fitting plastic fitments to a metal water pipe, for there had been trouble in a cold spell because of the action of frost on plastic fittings ; for instance, an annular ring had been pushed away.

MR. HOLMES was interested about the rats. He had wondered that if the pipe had been in any colour but black the rats might not have been attracted. But this was obviously not so, because with bitumen or tar they were not attracted to the piping. He asked whether Mr. Magg's pipe was all above ground.

MR. MAGGS answered that it was.

MR. HOLMES continued on the subject of the plastic fittings. In his own works, he said, they had obviously got long lengths of water pipes, and so forth, on which they had fittings made also in plastic and on which plastic-type welding had been performed. They had not had this experience of plastic fittings giving in cold weather. It was important that the installation was properly carried out, and he thought plumbers and the like or unskilled people were apt not to do such a good job.

MR. BRUTY (N.F.U.) asked whether any further work had been done on the use of hard polythene for rotating parts of fertiliser spreaders, such as the star wheel.

MR. HOLMES said that further work had been done. Such things as the star wheel they were trying to solve, and he thought that there were indications that they could do something about it.

MR. G. G. BALDWIN (David Brown Tractors, Ltd.) had a question about the use of polythene film in strawberry growing. He said that this crop was particularly suitable because it was mulched for many years, and asked whether there was any sort of film which would rot in the course of one season, so that the use of this film could be extended.

MR. HOLMES replied that he did not know. He thought that might well be a possibility in the light of one of the samples he had shown to them, for, if they could find a material which would be attacked by surface moisture sufficiently to rot in that time and yet was sufficiently durable to be extruded, they might find the answer.

MR. A. BLOOMFIELD (Surrey) asked whether polycarbonates, which in one of the tables shown to them had increased in use, were of any significance for agriculture.

MR. HOLMES' answer was that when they had come to look at the manufacture of polycarbonates they had felt that it did not have much in it for them. He did not think that in this country, apart from one or two applications, they had made an awful lot of progress.

MR. J. S. DUNN (Beds.) inquired what the fire risk was in using polystyrene, especially when it was in a foam state.

MR. HOLMES said that he had been quite right to raise that point ; it was one he himself should have mentioned. It was true that expanded polystyrene did not stand up so well to heat. They were involved in his company in giving flame and heat resistance to polystyrene. It was not cheap, but it could be done.

MR. A. ROSEN (Sussex) asked whether they were to assume that it was possible to store fertiliser outside in the plastic bags they had been shown for six to eight months.

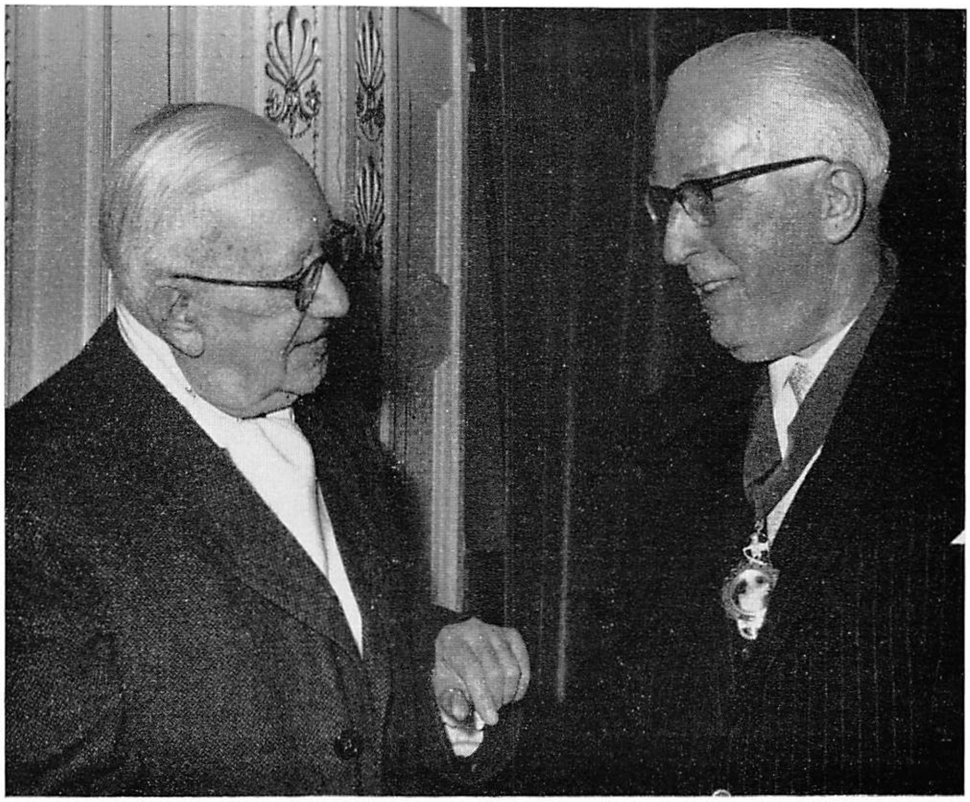
MR. HOLMES stated that experience had been that, apart from a certain difficulty in slipping in stacking, it was possible. If one could get the bags to stack without slipping, his company felt that they could be stored outside from the sack point of view without trouble.

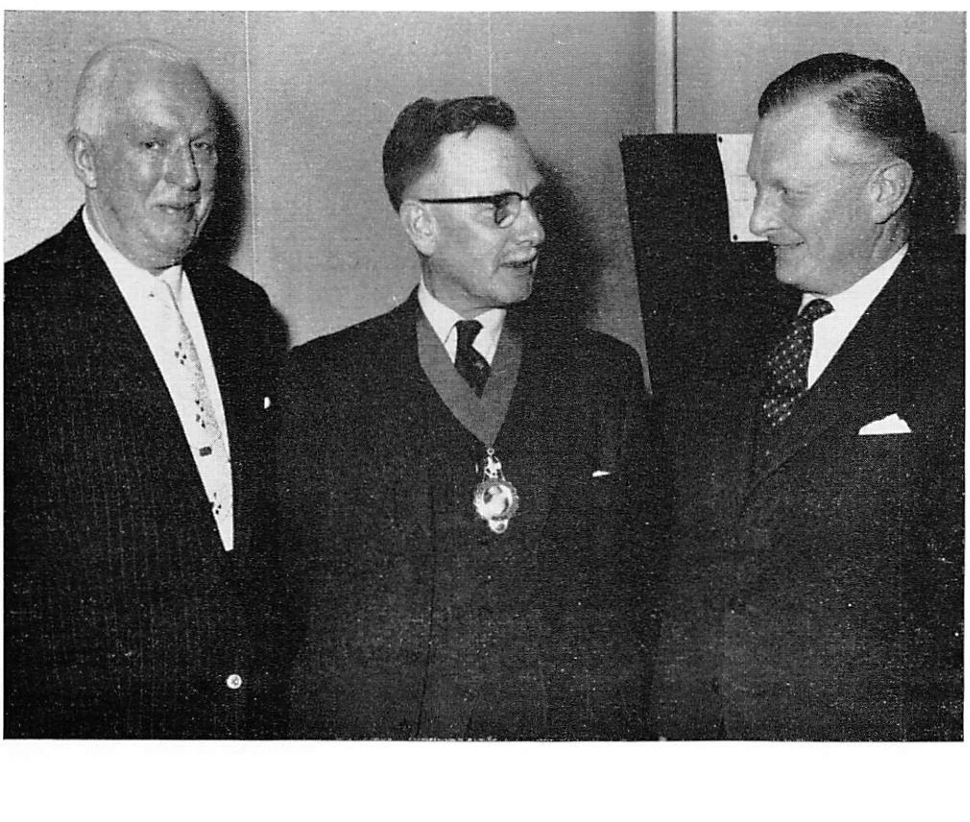
MR. J. V. CHARLTON (Northern Branch) asked if the speaker had any opinion on the thermal qualities of plastics for use in buildings.

MR. HOLMES recognised that when it came to higher temperature work there was a question of thermal deformation. That was why the sort of thing about which he had been talking was not suitable for transmitting steam, but was useful for cold work.

Lt. Col. Philip Johnson, Founder President, and Mr. J. W. Nolan, President, on the occasion of the Presentation of the Presidential Badge of Office, 1st May, 1962

(Mr. Nolan handed the Badge to Mr. Cameron Brown on the change of office at the A.G.M).





Mr. J. W. Nolan, Past President,
The President,
and Mr. John Davies

Speeches at the Annual Dinner of the Institution 1st May, 1962

MR. JOHN E. H. DAVIES (Vice-Chairman and Managing Director of Shell-Mex and B.P., Ltd.), proposing the toast of " The Institution," said that a lot was heard these days about the Common Market, and he ventured to suggest that there should be a general interdiction on adding to the torrent of words on this subject without first establishing one's allegiance and one's credentials. One's allegiance because the issue was too challenging and too serious to countenance fence-sitting, which always seemed to him a particularly worthless activity. One's credentials because these alone could intimate to the audience whether or not they were going to hear something worth listening to and, if not, to give them the chance to compose themselves in slumber for the likely period of hot air.

As for him, his allegiance was for Britain as a member of the Common Market. His credentials were twofold—first, that the greater part of his working life had been spent in an industry which, to some considerable degree, was a common market in itself. The oil industry lived and thrived on mobility and flexibility internationally. It had been fortunate to a very large degree in not having to contend with artificial obstacles in its colossal international balancing act. Restrictions on movement by fiscal or other means were less than in most industries. Standards both in quality and measurement were pretty universally recognised. Men had been trained to serve as well in the Arctic as in the Tropics, in highly industrialised parts of the world as in countries now in the first stages of development. Recognising the importance of oil to their economies, nations had sought to place the least possible barriers in the way of movement of finance, or of people, or of assets. All this added up to what he said originally. His industry had been a kind of common market on a world-wide scale already. His second credential was that he happened to have shared his working years since the war about equally between the E.F.T.A. countries, including our own, and the E.E.C. countries, and could claim to have been close to the main economic developments in both over these years.

To his mind, the real factors involved were not, however, the purely economic ones. Although he received a good deal of instruction on the matter when he was young, he had never really been able to comprehend the extraordinary efforts deployed by individual nations to ensure a continuing inflow of gold or its equivalent on international currency account. Of course, he realised that one could not afford to go down the drain either, but he could not help thinking that to the reasonable limit possible the net improvement in a nation's overall assets was much better represented in terms of higher living standards at home or, perhaps, even more to-day in terms of effective aid in under-developed areas than in the rather arid form of currency ledger entries or gold bars. To say nothing of the fact that for every debit there must be a credit and that, therefore, if to him there was to accrue a steady inflow of gold on currency account, it could only be offset by a steady outflow elsewhere. For these reasons, he found it hard to consider our membership of the Common Market solely in terms of our Balance of Payments account. It seemed to him that our great country had many responsibilities—

- to provide its own people with an improving standard of living ;
- to take its full part in the measures needed to safeguard peace ;
- to contribute usefully to the evolution of those countries settled and developed by our own kith and kin—that is, the Commonwealth ;
- to take our full part in the development of backward areas throughout the world ;
- to take our full part in the research field for the better knowledge and enjoyment of our own world and maybe beyond it.

These were our country's responsibilities, and we had to make up our minds whether we were going to be better able to face them teamed up with Europe and pooling our knowledge and competence with those across the Channel or not.

It was to see the whole question in far too restricted a way to try and make one's judgment on some risky forecast of what was likely to happen to our trading balance in the two hypotheses ; on the score of a single industry, one might well be able to estimate right—on the national plane he warranted one could do no more than guess. Equally it seemed to him to be getting the thing in the wrong context to see it all as an exercise in balance of power—military, demographic or economic. If the Common Market was a success, it could not be because it had procured, by isolating itself, a favourable internal situation in contrast with an unfavourable one outside. With some modifications, the responsibilities of the six countries now joined in E.E.C. were not so very different from those he had mentioned as ours. Theirs is not a defensive alliance, but an expansionist one, with all that implied for good for those surrounding it—with that much more good, he believed, if we too were a part.

He had done no more than put the questions he put to himself regarding Britain's membership of the Common Market, which incidentally, to his mind, was both an unfortunate and a misleading expression ;

why not European Enterprise or Joint European Venture ? There was, he hoped, nothing common about it whatever, and, as he had been trying to establish, " Market " was a hopelessly inadequate—nay, unworthy—term.

Might he be permitted to venture now on to a different field—a few words in the context of his joint European venture by a tyro in regard to the agricultural engineering industry and to the Institution. For both he could only believe that there was a brilliant future. For the industry because it seemed to him to be looking forward to the best of both worlds—one in which the number of those employed on the land must run substantially down as they had here while production went substantially up. The other where the increase in mouths to be fed must look to the agricultural engineering industry for a large measure of help in the means to feed them.

For the Institution, because its early realisation of the importance in an international sense of *qualified* capacity was vital. It had a contribution to make in this matter ; he thought, in fact, that this contribution should be made whether or not this country was in the Common Market.

What he wanted to suggest, in all modesty and without the fullest knowledge, was that in its educational programme there should be some emphasis on European farming practice and needs. Even more important, he thought that the Institution, which had played such a large part in the formation of the National College of Agricultural Engineering, should join the other voices which, he had no doubt, were already urging that the College should be European in outlook.

The College was unique in Europe. With the National Institute across the road, Silsoe would be doubly unique as a centre. One hoped that this example of British leadership would be maintained. One hoped, too, that the College would act as a catalyst for discussion and for dissemination of ideas on a European scale.

This was not to say that the College—and indeed the Institution—should in any way neglect consideration of the needs of the countries usually thought of when we said " overseas "—the Commonwealth and the underdeveloped countries.

He had travelled far and wide in the course of a few minutes. He was most grateful for the invitation to speak and for the kind way he had been received, and asked all present to drink to the health of the Institution, which had, in its 24 years of activity, travelled a very much longer and highly successful journey.

Responding to the toast, the PRESIDENT said that while his thanks must first be expressed to Mr. Davies for his kindness in proposing the toast of " The Institution," he must also thank him for the evidence of his high regard for the Institution and for what it was trying to do. While not the first President to wear the noble symbol of office, he would be the first to carry it through a year of office. While he could not hope to wear it with the same " presence " as his predecessor, he did hope to be able to meet his responsibilities with something of the *bonhomie* and conscientiousness which had been his outstanding attributes.

He was not unaware of the diversion from one's ordinary ooccupation which the Presidency of any professional institution entailed during the period of office, and that Mr. Davies should have enabled the Institution to enjoy Mr. Nolan's good services for his extended period he could only regard as another indication of a regard for the efforts to raise the standard of agricultural engineering to a high level of professional application and integrity.

He had used the term " integrity " with deliberation and intent. It was not enough that a member of a professional institution should be highly competent technically ; he should also be regarded as a man dependable on all ethical aspects concerning the prosecution of his profession. His opinion on any aspect of his particular technique should be regarded as being based on the technical aspects of the case and on no other, just as we expect from our doctor or lawyer.

The final seal on the Institution's professional status would be the granting of a Royal Charter. Then we should be able to call ourselves chartered agricultural engineers.

If, then, he could be said to have any theme in his talk, it was that of " professionalism " as the target of the Institution, because when that day came it would mean that the Institution had demonstrably acted in such a way as to ensure that its corporate members—that is, full members and associate members—were known to act technically and in full integrity. The President added, however, that this would not come about in a year or ten years. He had in mind quite some time before this happened. He should like to see it for himself, if only very much as a " has-been " ! He belonged to one of the three big institutions. His had 48,000 members, of whom over 25,000 were fully corporate ; that is, they were " chartered electrical engineers." It was founded in 1871 and the charter was not granted—presumably not earned—until 1921—50 years " in the wilderness." Similar progress would give us our goal in 1988. But he hoped that a more benevolent view was taken nowadays. Thus many of the men whose applications for associate membership were being scrutinised and evaluated now might well look forward to spending their last active years of work as " chartered agricultural engineers."

The Institution had, of course, achieved incorporation, and that was a vital step towards the full goal. So let us not be depressed at the distance between us and full " charterdom." Things were happening in the meantime, and the Institution was working towards facilitating in every way the training and examination of budding agricultural engineers. One of the major responsibilities of a professional Institution must be to foster and further—if necessary, to provide—the channels of educating and training the professional agricultural engineer.

Over the years, the examination boards and the education committees had put in much work, largely behind the scenes, and he was sure that the body members of both would not grudge his saying that the lion's share of the work fell on the chairmen. Mr. Hay had not found the past year easier than any of its predecessors. The boards and committees had to consider not only revision of the specified training syllabus, but they had to look ahead, forecasting and discussing future trends and the co-operation of interested bodies, such as the A.E.A. and the A.M.T.D.A.

But the highlight of the past year had been the placing of the seal of success on the efforts over a number of years of all who contributed to the setting into being of the National College of Agricultural Engineering. Many members of our Institution had contributed in drive and constructive advice to the actual fruition of the idea. He was particularly glad that " Sandy " Hay had been able to follow up his years of activity towards the foundation of the college by serving on the first Board of Governors, along with Mr. Douglas Bomford and Mr. John Chambers.

All these efforts would, however, be largely wasted if those responsible for employing agricultural engineers failed to give priority to " graduates "—if he might be allowed to use this title of the College and corporate members of the Institution. In his own industry, no one would nowadays dare to apply for a technical appointment of any standing—or indeed an appointment with any future hope of high technical standing—without being a corporate member of the Institution of Electrical Engineers.

He was not suggesting that college " graduation " be the only step to corporate membership, but it was the direct one. There was, too, the National Diploma in Agricultural Engineering, now recognised widely at home and overseas as a worthwhile target for the budding agricultural engineer. We were, as an Institution, grateful to those heads of various teaching centres who made it possible for young men to study the subjects required for the final diploma examination. The Council was particularly grateful to the Essex Education committee and Mr. B. H. Harvey, the principal of the Essex Institute of Agriculture, for the continued provision of facilities for holding the annual examination at Writtle—not so very far from the initial, if temporary, home of the National College.

Whatever the route and whoever the man who came to the stage of being a professional agricultural engineer —one day " chartered agricultural engineer "—he should well be able to earn his keep. Every day and in every way it was being forced on us that in the budding and bulging new world we, as a country, still fall behind the other leaders in the " applied field." We had the scientists, but lacked advanced technologists in anything approaching the numbers necessary to put our good ideas to full fruition, either here or abroad. He had not only in mind the manufacture of machinery and equipment, but the almost more serious field of overseas applications and the vital markets involved. We were having to compete with serious—indeed, frightening—competition, some from countries which we once regarded with equanimity, if not contempt. We were told that our own farm mechanisation was abreast of any other country's. In his own sphere he was sure we were ahead. But we must increase our technological resources if we were to reap any commercial advantage from other countries attempting to catch up. And what about all the *quite* undeveloped lands? He hoped that towards meeting these objectives of overseas development—resulting in British exports—manufacturers would be ahead of some of their counterparts of not so long ago by making use of the best agricultural engineering brains and recognising as at least one—and a major—qualification, the possession of evidence from our Institution that they were technologically fitted for this new frontier fight.

We were not without evidence that some of the major manufacturing and handling enterprises were recognising the part that the Institution is playing. Indeed, some of them—not yet enough, perhaps—were helping us in material fashion by enrolling as " Affiliated Organisations " and so giving practical support to the Institution's work. Many also encouraged their technical staff to apply for membership. But the best way to do this, and generally to give the Institution a helping hand, was to have in the appropriate advertisements for staff some such phrase as " corporate membership of the Institution of Agricultural Engineers essential."

We, as an Institution, could not sit back and expect all our help from outside. The status of a professional Institution depended in the end on the competence and conduct of its members. He made no apology for repeating what was said by his only " electrical " predecessor, Mr. F. E. Rowland, in referring to this point and emphasising the need for raising the status of a profession from within. While we looked at what the Institution was doing towards furthering the technical education of budding agricultural engineers, we might well feel that practical support was being given by the donors of scholarships—the Dunlop Rubber Company and Shell-Mex and B.P., Ltd. To them the thanks of the Institution were due.

But whatever might go on in London, at Institution headquarters, this can only be in the end a reflection, although, no doubt, an intensification, of what went on all over the country at, and in connection with, the various branches. We could not expect a healthy head —or were we the " heart "—if the limbs were disinterested or apathetic. And he did indeed, if metaphorically, take off his hat to the branches, which were vital to the full life of the Institution. In particular, his thanks, on behalf of all, went to the chairmen, secretaries and committees. If he had any idea of what went on, he had an idea that, above all, the branch secretary was the man who carried the burden in the heat of the day.

At this point—at which he had no briefing whatsoever —he insisted on saying " thank you " to the secretary, Mr. Slade. In the early years of any Institution so much depended on the Secretary. Presidents came, Presidents went; even committee chairmen did have some degree of turnover. But the secretary was the sheet anchor—should he better say " buoy "—round which the Institution's affairs " backed " and " veered " with changing winds, but were quietly and competently held under control. Should we say that the President is the temporary skipper? But the Secretary was the pilot. And never in the progress of our Institution would the pilotage be so difficult as in those past years. He could only hope that his own

" skippering " would not too much meet the disapproval of the pilot. He knew only too well how dependent he would be on him and on his crew.

He was, indeed, coming to an end by thanking the outgoing President, Wilfrid Nolan. Thanks to Mr. Davies, he had not only ably filled the post, meeting all responsibilities, but he had done so for the unprecedented term of three years. He had thus been able to help the Institution to come through a period of difficulty and to ensure that his hand removed from the helm left the craft well set in a definite and directed course. But, above all, he had done so with an unmatchable equanimity of temperament and, as he said earlier, a *bonhomie* which would be most difficult ever to equal—he could not even attempt to do so.

While, therefore, he had finished by confirming his opening words of thanks to Mr. Davies for so kindly proposing the toast of the Institution, he also asked the members of the Institution present, and any of the guests who cared to echo his sentiments, to drink to the health and continued prosperity of " our immediate Past President and friend, Wilfrid Nolan."

MR. NOLAN proposed the toast to " The Guests." That function was a special one for him and he would go away with many happy memories. Before proceeding with this present task, Mr. Nolan asked to be allowed to digress for a few moments, because he had been very touched by the kind sentiments expressed that evening. He referred to the support he had had from members of Council and from the Secretary. In expressing gratitude to them, he also took the opportunity of expressing gratitude to his wife. She had contributed to his years of service with the company, and at the end of August he would have completed 42 years. Her nspport had enabled him to do all that he had done.

On behalf of the members, Mr. Nolan said how pleasing it was to see more ladies among them that night ; he hoped their numbers would increase. The President had already referred to Mr. Davies—his interest was a compliment to the Institution, and Mr. Nolan was glad that Mr. Davies had spared time to be there that night.

Going round the table, there were a number of other people to mention, said Mr. Nolan. First was the President of the National Farmers' Union, Mr. Harold Woolley—a man of outstanding wisdom, knowledge, and experience of all matters relating to the farming industry.

Then they were honoured by the presence of some other old friends, the members of the Agricultural Engineers' Association. They were particularly pleased to see the newly-elected President, Mr. Tom Cummings. On behalf of the Institution, Mr. Nolan wished Mr. Cummings every success in his year of office and hoped the industry which the A.E.A. represented would enjoy even more success, especially in the export field. It was a matter of satisfaction that relations between the Institution and the A.E.A. were becoming even stronger.

He said it was a matter of regret for him to have to say that Mr. Peter Scott, President of the A.M.T.D.A., was unable to be with them because of his health, and conveyed wishes of the Institution for his early recovery. Mr. Nolan also welcomed the representatives of the electrical industry present, and the two visiting speakers at that day's conference, Messrs. Wallace and Holmes.

It was, said Mr. Nolan, difficult to express adequate thanks to the support that the Press was giving in this industry, in particular their wide reporting of Institution meetings and conferences. Mr. Nolan then invited all members to join with him in the toast to the health and prosperity of their guests, coupled with the name of Mr. Tom Cummings.

MR. T. CUMMINGS (President of the Agricultural Engineers' Association), responding, said he felt he ought to tell the Institution that its privileged guests were feeling particularly friendly towards the Institution for the food and wine they had been given that night. But the friendship extended far beyond hospitality. It was a pleasure to be there with Mr. Davies, whose company was well known and also very generous. Mr. Cummings referred to the highly successful film about the agricultural engineering industry, with which project Mr. Davies's company had co-operated with the A.E.A.

He also mentioned Mr. Woolley and his services to agriculture, and also the services that farmers extended to the community. Agricultural engineers were glad of that because it demanded the use of machinery to maintain the farming contribution.

An " immense tribute " was paid by Mr. Cummings to Mr. Nolan, who had done so much to encourage the status of the agricultural engineering industry and to maintain the standards for which his Institution was so justly known. That occasion provided one more opportunity to exchange ideas relative to the business of those present. Mr. Cummings thought that the fact that they had been able to do that that evening warranted the most sincere thanks of the guests.

ELECTIONS AND TRANSFERS

Approved by Council at their Meeting on the 27th March, 1962

ELECTIONS

ASSOCIATE MEMBERS		Bull, K. G.	Bedfordshire
		Chittey, E. T.	Buckinghamshire
		Plant, A.	Worcestershire
		Rae, W.	Angus
		Spofforth, B. C.	Gloucestershire
		Steele, M. J.	Midlothian
		Taggart, C. W. N.	Aberdeenshire
		Wilton, B.	Cambridgeshire
	Overseas	Bowness, A. H. F.	South Africa
		Buck, M. F.	Kenya
		Hudson, N. W.	Southern Rhodesia
ASSOCIATES		Adams, J.	Lanarkshire
		Cameron, J.	Fife
		Waddell, C.	Northumberland
GRADUATES		Alcock, J. C.	Worcestershire
		Ambler, L. D.	Berkshire
		Catt, W. R.	Wiltshire
		Draper, I. C.	Lincolnshire
		Eddison, H. P.	Lincolnshire
		Gray, H. J. H.	Ross-shire
		Munsen, J. P. J.	Essex
		Pollock, J. R.	Ayrshire
		Rose, N. J.	Bedfordshire
		Rutherford, I. R.	Shropshire
		Watson, P. S.	Cumberland
STUDENTS		Bateman, J. B. D.	Essex
		Bomford, P. H.	Berkshire
		Coelho, A. S. B.	Yorkshire
		Howard, P. W. J.	Essex
		McLaren, E. A.	Ayrshire
		Tadman, P.	Nottinghamshire

TRANSFERS

FROM ASSOCIATE MEMBER TO MEMBER		Balls, D. W.	Essex
FROM ASSOCIATE TO ASSOCIATE MEMBER		Parry, D. W.	Warwickshire
		Gibson, J.	Staffordshire
	Overseas	Jones, T. R.	Uganda
FROM ASSOCIATE TO COMPANION		Souter, D. S.	Aberdeenshire
FROM STUDENT TO ASSOCIATE MEMBER	Overseas	Coles, E. D.	Southern Rhodesia
FROM GRADUATE TO ASSOCIATE MEMBER		Moore, S.	Co. Antrim
FROM STUDENT TO GRADUATE		Neale, M. A.	Cambridgeshire

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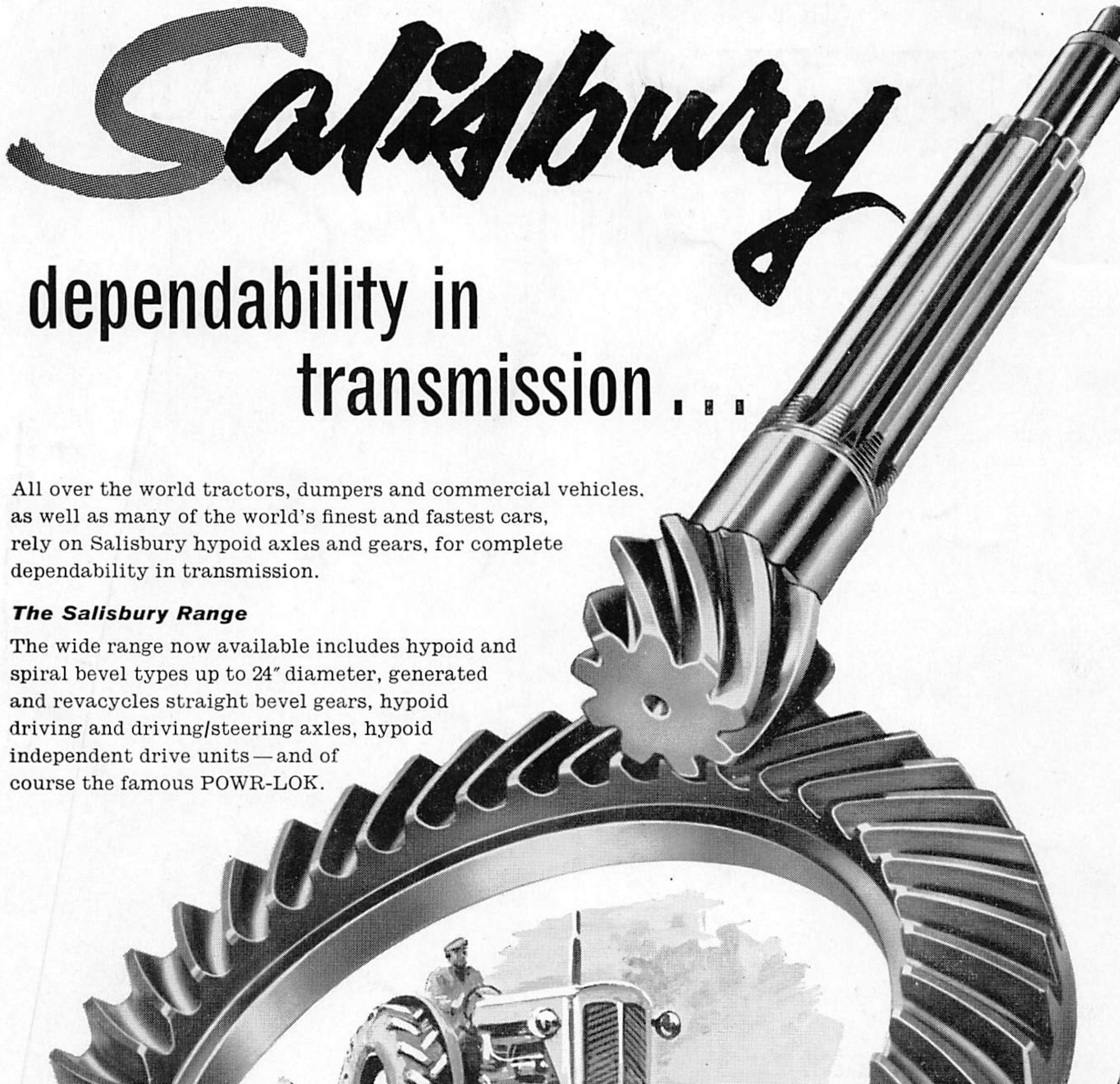

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