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INSTITUTION OF AGRICULTURAL ENGINEERS

VOL. 16 NO. 4 - OCTOBER 1960

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JOURNAL AND PROCEEDINGS OF THE INSTITUTION OF AGRICULTURAL ENGINEERS

VOLUME 16 - NUMBER 4 - OCTOBER, 1960

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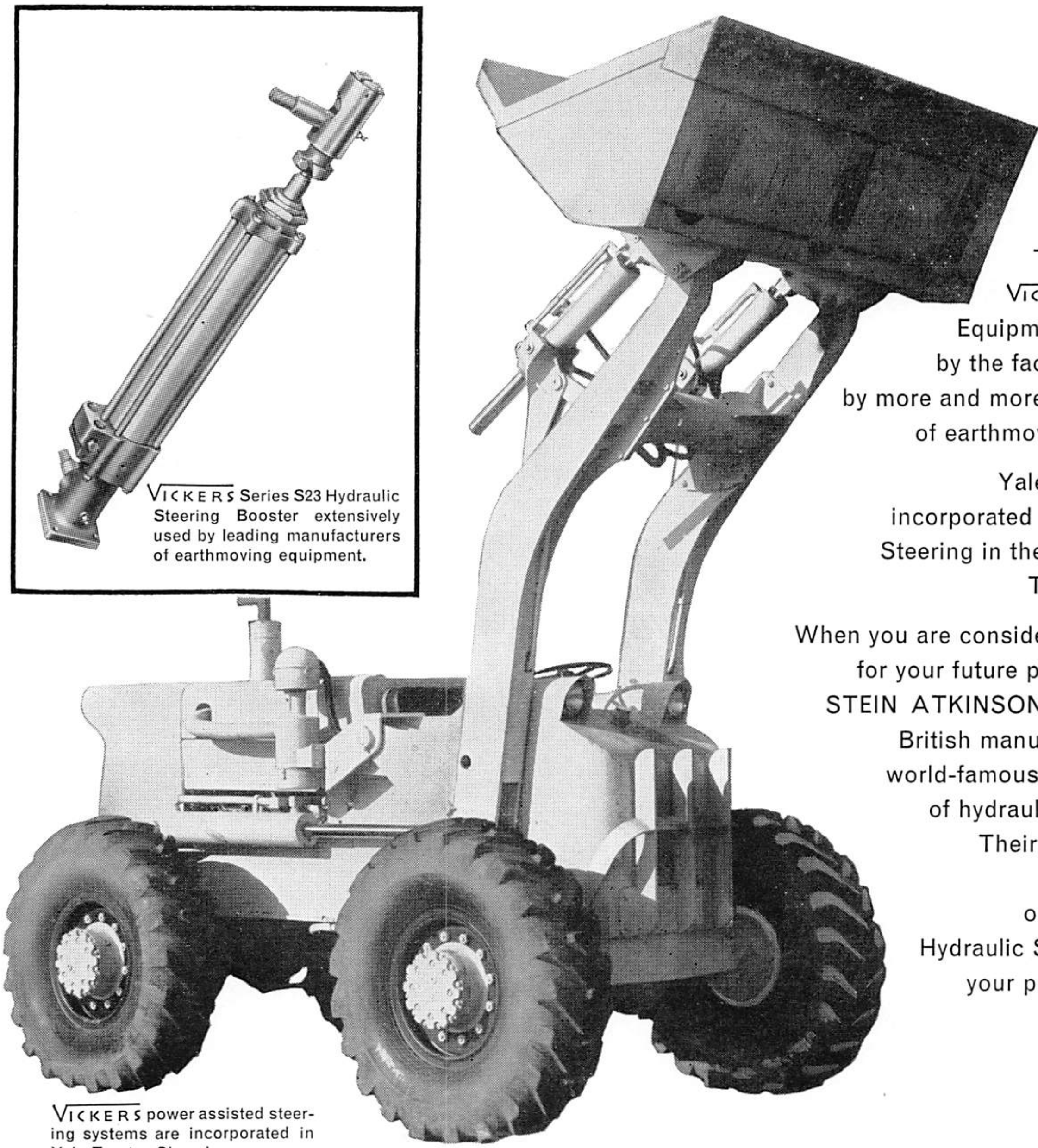

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INSTITUTION NOTES

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A New Branch

AT an inaugural meeting held in Exeter on October 19th, a South-Western Branch of the Institution was formed. The chair was occupied by the President, Mr. W. J. Nolan, until the election of the Chairman of the Branch.

The area covered by the Branch will be that lying to the west of a line from Bridgwater to Bridport, and of the 54 members living in that area nearly 40 were present at the meeting.

Officers and Committee were elected as follows :

Chairman : Mr. J. E. Bywater, M.I.Mech.E., M.I.Agr.E.
Vice-Chairman : Mr. G. A. Iles, A.M.I.Agr.E.
Hon. Secretary : Mr. J. B. Paterson, N.D.A., A.M.I.Agr.E.
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Mr. D. H. Mingo, A.I.Agr.E.
Mr. R. G. Pollard, G.I.Agr.E.
Mr. G. F. Shattock, N.D.Agr.E., A.M.I.Agr.E.
Mr. R. Zeale, A.M.I.Agr.E.

The Committee has already held its first meeting and given consideration to a programme of Open Meetings for the current session and suitable places for the holding of such meetings. The first Open Meeting will be held on December 1st ; particulars are given on page 103.

National College of Agricultural Engineering

A meeting of the Board of Governors of the College was held in October, when, among other matters, consideration was given to applications received for the post of Principal. Subsequently, the Academic Committee has met to give consideration to the courses to be provided, and is to meet again in November. The Board will have a further meeting in December, after which the appointment of the Principal will be announced.

Membership

Following the circulation to members of a letter from the Chairman of the Membership Committee, a number of applications for transfer in grade have been received.

Those members who feel they have the necessary qualifications, and who have not yet applied, are reminded that the Committee will welcome applications.

Membership Certificates

Members are again reminded that these are obtainable on request from the Secretary, unframed copies being sent free of charge ; framed copies at a cost of 15/-.

A Correction

In the last issue of the Journal an error was made in reporting the remarks made by the Founder-President, Lt.-Col. Philip Johnson, on the occasion of the presentation of his portrait to the Institution.

On page 65, column one, Colonel Johnson was reported as having quoted Oliver Wendell Holmes that " conceit keeps a man's mind sweet and renders it pure." In fact, the correct quotation, as given by Colonel Johnson, is : " Conceit is to the human mind as salt is to the ocean—it keeps it sweet and renders it endurable."

As the Founder-President remarks, the circulation of the Journal now being so wide, he would not like to think that any of his friends in America would be in a position to accuse him of a misquotation of an American author !

Our apologies are extended to the Colonel for this error.

Council Room Donation

A handsome Electric Clock is the latest addition to the Council Room, the donor being Mr. P. G. Finn-Kelcey.

FORAGE HARVESTERS

by R. Q. Hepherd, B.Sc.(Agric.), A.M.I.Agr.E.

Presented at an Open Meeting of the East Midlands Branch on 10th February, 1960.

Introduction

THE N.I.A.E. has in recent years amassed a considerable amount of data on the field performance of forage harvesters, partly as a result of tests of machines carried out by the Agricultural Testing Department at the request of the manufacturers concerned.

A number of Papers in which the N.I.A.E. Testing Scheme has been described and discussed have already been read before members of this Institution (1, 2, 3, 4), and it will therefore suffice to say that the Testing Scheme is primarily a service to manufacturers whereby the performance of their machines can, if they so desire, be assessed by an independent body. A farmer may of course obtain a direct benefit if, when selecting a machine, he makes use of the reports which are agreed for publication with the manufacturers. He also obtains an indirect benefit, particularly when a machine is tested in the prototype or, preferably, the pre-production stage of its development, because as a result of a test an improved machine comes on to the market.

Although testing occupies only a relatively small proportion of the Institute's facilities and personnel, the existence of the Testing Scheme is also of value to the Institute itself in several ways. The close contact between the Testing Department personnel, farmers, advisers and commercial organizations serves as one channel through which the problems of each can be brought to the attention of those engaged in research or development, both at the N.I.A.E. and research stations elsewhere.

On the other hand, the results of research and practical experience, both at the N.I.A.E. and elsewhere, are often of value in interpreting the results obtained during a test, and thus can, indirectly, be transmitted to both manufacturers and users.

This Paper is, in the main, a discussion of some of the problems encountered when developing the forage harvester testing technique used at the N.I.A.E., and of some of the facts brought to light by testing and other work.

The Performance Required of a Forage Harvester

The main requirements of a forage harvester can be summarised as follows : The machine should—

1. Cut (or pick up) neatly at the required height under all conditions.
2. Chop or lacerate the crop to the required degree.
3. Cut and deliver the crop without undue losses, and in a clean condition.
4. Work at a satisfactory rate when using standard agricultural tractors or power units.
5. Be reasonably easy to operate, service and maintain.
6. Be reliable, both mechanically and in the sense that it will work under a wide range of crop and weather conditions.

During N.I.A.E. tests the emphasis is on aspects of performance other than mechanical reliability. This is largely because, for a number of reasons, it is not at present practicable to run each machine for more than 50 to 100 hours (about one season's work on a fairly large farm). Although most of the mechanical faults of a machine are in practice detected during this running period, the period is usually not sufficiently long to enable estimates of the working life of a machine or its components to be made. Manufacturers often run machines for many times this period during the course of development, and are often in a better position to make such estimates.

On the other hand, the N.I.A.E. testing staff can often record certain aspects of performance (*e.g.*, quality and rate of work) in greater detail and with greater accuracy than can manufacturers, since the instruments, equipment and laboratory facilities available to them are better than those of most manufacturers. In practice, therefore, manufacturers often use the N.I.A.E. testing service to provide data on their machines' performance which they cannot readily obtain themselves, in addition to the other more obvious reasons for requesting an N.I.A.E. test.

Some aspects of performance are difficult to measure and express in numerical terms (*e.g.*, items 1, 2, 3 and 5 in the above list), but a more serious obstacle is that the figures obtained are sometimes difficult to interpret (for example, the importance of relatively small differences between machines in height of cut or length of chop is unknown). In such cases, the conclusions of a team of experienced observers, based both on numerical evidence and observations, must remain the basis of an assessment of performance. The number of such cases is of course being steadily reduced as the necessary basic data on the performance required becomes available as the result of research. However, research into the effects of new machines or methods, from the point of view of crop or animal husbandry, may take longer than the development of the machines themselves. When relatively new types of machine appear, it may be therefore some time before certain aspects of performance cease to be controversial. Some of these aspects are discussed below.

Height and Neatness of Cutting

For most forage harvesting requirements in this country the flail mechanism appears likely to supersede other types of cutting mechanism now in use, partly because the flails are much less easily damaged than the other common mechanisms, but also because the flail mechanism can also be used to convey the grass. Moreover, the flail mechanism is a basically simple one, and this simplicity is reflected in the relatively low price of many flail machines.

During the N.I.A.E. tests it has been found that cylinder mowers and reciprocating knife mowers can in often practice be set to cut slightly closer (1 to 2 ins.) to the ground than can conventional impact-cutting mechanisms. The difference in cutting height is probably due to the fact that most present-day flail mechanisms, unlike most of the other mechanisms, do not " float " at a predetermined distance from the ground surface directly beneath the cutting rotor, but cut at a height which is pre-set in relation to the machine and tractor wheels. Flail machines therefore in practice have to be set somewhat higher in order to prevent the flails or cutters striking undulations in the soil surface, and thus causing the silage to be contaminated with soil. Under British conditions, however, the fact that the stubble may be slightly longer than is normal when a mower is used does not appear to be a serious disadvantage in practice (16) ; although when only one cut is to be taken, as for example in an arable silage crop, it is obviously advantageous to cut as low as possible in order to obtain the maximum possible yield. (In oats, and tares, the loss in yield per inch of stubble height is likely to be of the order of 2%, but losses for this reason in maize and other tall arable crops will be less.)

Where successive cuts are to be taken in a season the advantages of a very short stubble are not likely to be great, since it is probable that the rate of recovery is more rapid where the stubble is left relatively long. There is some experimental evidence on the effects of height of cutting on rate of recovery and total crop yield over the season to support this view (16).

Impact-cutting machines leave the tips of the stubble in a relatively ragged condition, but at present there is no experimental evidence that this factor influences the subsequent rate of growth of the crop. Rather superficial observations made during N.I.A.E. tests during 1958 (6) and 1959 suggest that there is little difference in this respect between the two basic types of cutting mechanism.

An objective study of the relationship between the height and method of cutting of various crops and their total yield and subsequent rate of growth is needed. Such a study is impracticable during the course of an N.I.A.E. forage harvester test, and, indeed, is rather outside the scope of an engineering institute since a relatively complicated and long-term experiment into what is essentially a crop husbandry problem would be involved.

Height of cutting can be quite accurately measured, and doubtless a technique for recording the degree of fraying of the cut stems could be evolved, but since the importance of any differences in the data recorded for different machines is not at present known, the expenditure of time and labour on such measurements cannot at present be justified during routine N.I.A.E. harvester tests. Observations on the condition of the stubble, together with a relatively few measurements of height of stubble, are, however, taken in each field after each machine has been set to cut as low as is considered practicable.

Laceration or Chopping

The two processes (laceration and chopping) each have their advocates, but the experimental evidence in favour of one process or the other is scanty and in some cases conflicting. A further complication is that certain machines, including flail types, both chop and lacerate the crop. There are two inter-related aspects to the problem—the mechanical and the biological. From the point of view of mechanical handling, it is clear that a finely and evenly chopped material is required. It is for this reason that harvesters incorporating either a gang-mower principle (which are only capable of tackling crops up to about 8 ins. high satisfactorily) or those incorporating a more-or-less conventional chopper/blower mechanism are preferred for use in conjunction with many types of grass-drying plant, or where the cut material or the made silage is to be handled mechanically. On the other hand, it has been suggested that lacerating processes release and spread more of the cell sap than chopping, thus ensuring that the required fermentation proceeds more rapidly, and a better quality silage results. A survey of the information at present available only leads to the conclusion that, under most British farm conditions, some form of mechanical treatment is better than none (probably because mechanically-treated herbage is easier to consolidate evenly to the required degree) (7, 8). Methods of measuring chopping (9) and laceration (10) have been used in the past and could doubtless be adapted for test purposes. The degree of laceration or chopping is not, however, recorded numerically during N.I.A.E. tests, again mainly because of the difficulty in interpreting the results. However, samples are photographed to give an impression of the type of work done by different machines under different conditions (Fig. 1).

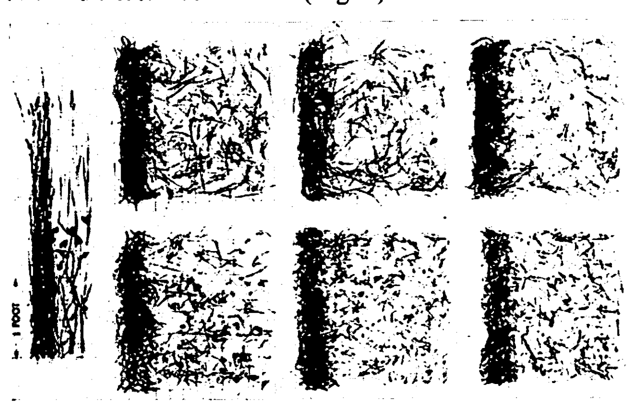


FIG. 1
TYPICAL SAMPLES OF CROP HARVESTED BY FIVE DIFFERENT MACHINES

Left : Standing crop.
Top row : Product from three lacerating machines.
Bottom row : Product from two chopping machines, one having been set to give two different lengths of crop.

Research into methods of achieving high-quality silage and into existing silage-making processes is at present proceeding at several centres, and in due course it may be possible to give machine designers more guidance on the type and degree of mechanical treatment required. Some Dutch work involves far more severe mechanical treatments than is normally obtained by means of present-day machines (11). Laboratory-scale experiments suggest that severe crushing (sometimes termed maceration) improves silage quality, but the results of farm-scale experiments are still awaited.

Certain flail harvesters can be adjusted to alter the length of chopping to some degree, but for straightforward direct-cutting of silage crops such a provision is rarely essential. When picking up from a swath, however, flail machines usually leave the crop in a somewhat longer condition than when direct-cutting the same crop. In such circumstances, and particularly if a field is to be partly direct-cut and partly picked-up, such adjustments can make it possible to deliver a material of more uniform length to the silo. (In practice, direct-cutting appears to be the normal procedure.) Material under about 2 to 4 ins. long or over 6 to 8 ins. long can be difficult to handle or to stack by hand or by means of fore-loaders, elevators or buckrakes ; it is suggested that where these commonly-used grass-handling methods are employed the length of the material produced by a machine should, in the main, be somewhere between the above limits. Very short material, although easy to spread, is somewhat dangerous to consolidate with a tractor unless the sides of the clamp or silo have retaining walls.

Forage harvesting and silage-making techniques are at present developing quite rapidly, and the limits of length of chop suggested above are by no means figures that are universally applicable. New methods of silage and grass handling may well demand a more uniformly and shortly chopped material, which, in general, cannot be produced by existing flail harvesters. The flail may eventually come to be considered rather more as a reliable trouble-free cutting mechanism ; its present chopping, lacerating and conveying functions then being taken over by other mechanisms. This trend can be seen in certain of the American flail machines which have recently entered this country in small numbers.

Power Consumption and Crop Delivery

Measurements taken during N.I.A.E. tests have shown that the efficiencies of different forage harvesters, in terms of output in relation to power consumption, vary quite widely. Analyses of test results to date suggest that, where high power consumptions per ton of material conveyed were recorded (Fig. 2), relatively large quantities of air were also being moved, but that in the case of certain flail machines only a small proportion of this air was passed up the delivery chute.

Two harvesters having chopper mechanisms which impelled the material up a duct rather than fed it into a conveying air stream were the most efficient types so far encountered (Fig. 2 : Machines D and E). However, it is quite possible that other machines of this general type are less efficient since too few machines of this class

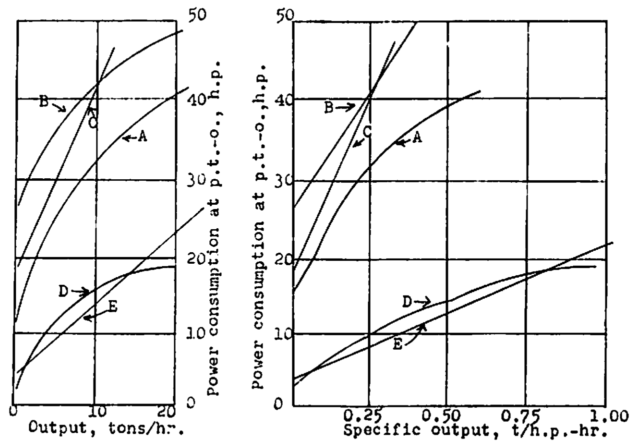


FIG. 2

POWER CONSUMPTIONS AND OUTPUTS OF FIVE DIFFERENT MACHINES IN THE SAME FIELD, 1958

Machines A and B : Flail types.
Machine C : Lacerating fan type.
Machines D and E : Chopper types.

have been tested for general conclusions to be drawn. Nevertheless, it is obviously possible to produce machines which have a relatively high efficiency (a specific output of about 1 ton of harvested crop per h.p./hr.).

A number of makes of flail forage harvesters have been tested, and there is little doubt that, as a class, their power consumption is relatively high. In general, their specific outputs seem to be between 0·3 and 0·5 tons/h.p./hr. The efficiency of a flail machine, if considered as a fan, may well be only about 5%. It is probably impossible to design a flail machine so that its efficiency as a fan is high, but there is no doubt that much still remains to be done to reduce the power wasted through air turbulence and unnecessary movement of air, and also in smoothing out the path of both the air and the material through machines so that there are no sudden and power-consuming changes of direction or velocity.

Crop Losses

Crop losses, although normally low, when suitable trailers are used, can occur under certain circumstances. Until sufficient space is available to allow loop turns to be made, losses occur duiing turns with rear-delivery machines ; however, as a rule, such losses represent a very small proportion of the total yield, and it is very doubtful if the provision of a delivery chute which automatically " follows " the trailer during turns is justifiable in view of the mechanical complications and additional cost involved. (There is perhaps a case for the provision of such an attachment as an optional extra.) Chutes which are rotated manually from the tractor are, at present, not always satisfactory because the chute cannot be swung sufficiently quickly and easily through the required arc, due to the design of the chute-rotating mechanisms.

More serious losses can occur when the 40-in. flail machines are used to pick up from a 5-ft. swath, for obvious reasons. This loss can be greatly reduced, often to negligible proportions, by fitting two swath boards to the mower. Nevertheless, a somewhat greater width of cut is desirable for this and other reasons, particularly in relation to rate of work (as will be discussed later).

In practice the most common cause of serious losses is the use of unsuitable trailers. Some form of top cover is essential, particularly under windy conditions, if trailers are to be fully loaded without loss of crop.

Since, by the use of suitable trailers and operating methods, crop losses can be reduced to negligible proportions, it is not normal to record losses during N.I.A.E. tests.

Soil Contamination

The effects of soil contamination on the silage-making process and on the stock are not precisely known. Past research and experience suggests that the presence of patches of heavily-contaminated crop can cause "pockets" of spoilt silage. Forage harvesters in general do not cause pockets of contamination for, if it occurs at all, the soil is more or less evenly spread over the mass. The " danger level " of soil contamination from the point of view of silage quality is not, however, known. So far as stock are concerned, the danger level will of course depend on the degree of contamination in relation to the type of stock and the amount of silage being fed. The average level of soil contamination (expressed as % silica in the dry matter) has been shown to be about 3½% silica in the case of sugar beet tops for silage (15), and other analyses have yielded figures up to at least ten times this value. For N.I.A.E. test purposes it has been assumed that contamination of less than about 5% silica were acceptable in practice. (It is understood that silage begins to appear dirty at a contamination level of about 10%.)

During 1958 and 1959 the silica analyses of crop from a total of seven machines (including four flail types) were recorded (Table I). In 1958 (6) there were only small differences at similar heights of cut in the silica contents of crops cut by flail machines and other types, except under one set of circumstances (Fig. 3). An arable silage crop was being cut by an in-line machine under very wet conditions, and mud from the tractor wheels was deposited on the crop in front of the machine. The mean contamination was 5·62% silica, and the highest reading 6·75% silica. No contamination occurred when an offset machine was used. In 1959 similar degrees of contamination were recorded (12), a higher contamination than normal again being recorded when using an in-line machine in an arable silage crop, but under very dry conditions, and when the surface was extremely rough with numerous easily-broken clods resting on it. An average reading of 3·75% silica was obtained, the highest individual reading being 7·0% silica. In this case, the contamination could have been reduced if the farmer concerned had been willing to accept a slightly longer stubble, so that the flails could have been set well clear of the clods on the surface at all times. Readings as high as 22% silica were obtained when using another machine in this field, probably because this machine was set to cut slightly lower.

TABLE I

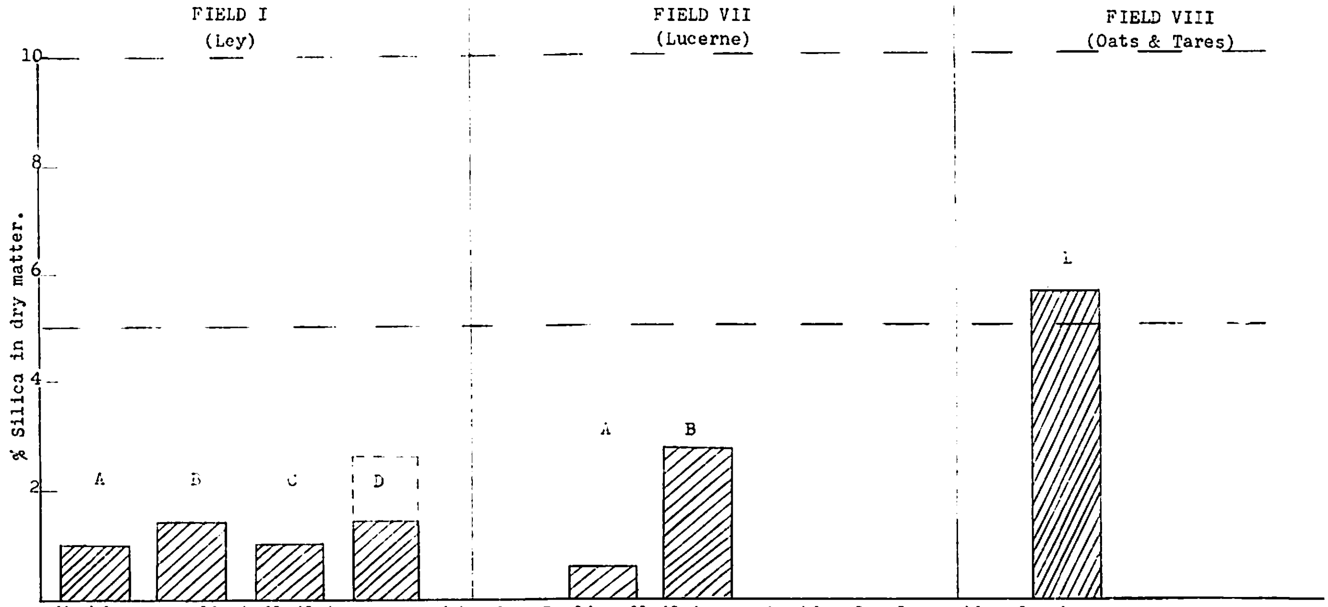
Silica and Soil Content of Samples—% of Dry Matter

Crop	*Ley*			*Ley*		*Lucerne*		*Oats and Tares*	*Ley*		*Lucerne*	*Oats and Tares*
Date	*May, 1958*			*June, 1958*		*June, 1958*		*July, 1958*	*May, 1959*		*July, 1959*	*June, 1959*
Machine	*Offset Flail*	*In-line Flail*	*Pick-up*	*In-line Flail*	*Pick-up*	*Offset Flail*	*In-line Flail*	*In-line Flail*	*In-line Flail*	*In-line Flail*	*In-line Flail*	*In-line Flail*
Mean silica content of samples ..	0·94	1·44	1·50	1·61	1·33	0·58	2·76	5·62	1·49	2·24	1·42	3·75
Mean silica content of standing crop	0·97	0·97	1·41	1·64	1·38	0·50	0·50	1·22	1·45	1·45	0·72	1·72
Dry soil added to green forage %..	0	0·13	0·04	0	0	0·02	0·60	1·1	0·01	0·3	0·2	0·9

Both the conditions under which an abnormal degree of contamination occurred were somewhat exceptional. There is little doubt that the risk of contamination as a result of careless operation of flail machines is higher than with other types, but with all types of forage harvester it is highly desirable that the field surface should be kept as level as possible, particularly if it is desired to cut low. Under normal conditions on grassland flail machines rarely need add more than 2% silica to the harvested crop, and often will add even less.

Rate of Work

From N.I.A.E. test reports and other publications (6, 12, 13, 14) it will be seen that the overall rate of work of commonly-used types of forage harvester varies between say 4 and 14 tons/hr., with the higher-output machines giving outputs of between about 8 to 15 tons/hr., depending on the conditions (Table II). These figures were in the main obtained on machines driven by medium-sized tractors (about 40 h.p.) and when drawing the trailer behind the machine. The latter



Machine A - offset flail type. Machine B - In-line flail type. Machine C - lacerating fan type. Machine D - pick-up (chopper) type. The broken line indicates the degree of contamination when two swaths were put together by means of a side-rake.

FIG. 3
AVERAGE SILICA CONTENTS OF SAMPLES TAKEN FROM THE DELIVERY POINTS OF THE MACHINES

practice entails changing each trailer after loading, an operation that should take one man between two minutes and four minutes if a satisfactory system is used. Changes can thus occupy between 10% and 30% of the total working time (12, 13, 14). To keep the number of changes to a minimum it is essential to use as large trailers as possible, and adapt them to carry as large loads as possible. Since heavily-loaded trailers cannot normally be drawn over the silo satisfactorily, it is now common practice to dump the loads close to the silo and then transport them on to the silo by means of a buckrake, loader or elevator.

Delays due to trailer changes can of course be eliminated by using side-delivery machines. An additional man and tractor will then be required. If an efficient system is used, side-delivery can result in a slightly higher rate of work. In most cases, however, the additional costs involved are difficult to justify even if the additional tractor and man required are available, a conclusion that the N.A.A.S. has also formed (5).

Loading rates (rates at which the crop is loaded into the trailer) of between 10 and 15 tons/hr. are quite commonly achieved during N.I.A.E. tests of present-day machines. The N.A.A.S. survey (5) quoted above shows that loading rates of 10 to 15 tons/hr. are also quite common under farm conditions. On two farms rates of 18 tons/hr. and 26 tons/hr. respectively were recorded when using larger machines than are normally used. If the work is well planned a skilled team of four men (one on the harvester, one ferrying trailers, one using a fore-loader or buckrake to transport grass from the trailer tipping point and one spreading grass on the silo) could handle grass without undue effort at an overall rate of up to about 10 to 14 tons/hr. (During N.I.A.E. tests the farmers concerned are responsible for the transporting and ensiling of the crops.) With the popular types of relatively cheap present-day machines, however, such rates can only be achieved when, by chance, field and crop conditions are favourable and crop yield, width of cut and forward speed practicable are matched correctly, since there is an insufficient reserve of tractor power and therefore output to enable high rates to be obtained under all conditions (Table II).

TABLE II

RATES OF WORK EXTRACTED FROM N.I.A.E. TEST REPORTS Nos. 197 AND 227

Field No.	*Lundell 60 Harvester, 1958**				*Lundell 40 Harvester, 1959*			
	Net Output		*Overall Output*		*Net Output*		*Overall Output*	
	tons/ hr.	*acres/ hr.*	*tons/ hr.*	*acres/ hr.*	*tons/ hr.*	*acres/ hr.*	*tons/ hr.*	*acres/ hr.*
1	10·0	2·0	6·7	1·3	14·3	2·1	8·3	1·2
2	16·5	1·8	11·6	1·3	†10·7	1·3	8·4	1·0
3	13·0	1·5	8·5	1·0	7·9	1·6	5·7	1·1
4	15·5	1·6	11·2	1·2	9·8	1·7	5·7	1·0
5	17·0	1·3	9·5	0·7	—	—	—	—
6	—	—	—	—	11·0	1·2	7·2	0·7
7	13·2	1·2	8·9	0·8	—	—	—	—
8	11·6	0·7	9·3	0·6	†6·7	0·8	4·3	0·5
9	—	—	—	—	7·8	0·7	5·6	0·5
11	—	—	—	—	8·4	1·3	6·4	1·0

* Nuffield DM 4 tractor used throughout.
† Ferguson 35 tractor used in these fields ; Nuffield DM 4 or Fordson Major tractors in the remainder.

To achieve an overall rate of 10 to 14 tons/hr. under all conditions a considerable reserve of machine capacity will be required (loading rates of 14 to 20 tons an hour must be practicable). No flail machines have consistently attained such rates during N.I.A.E. tests largely because

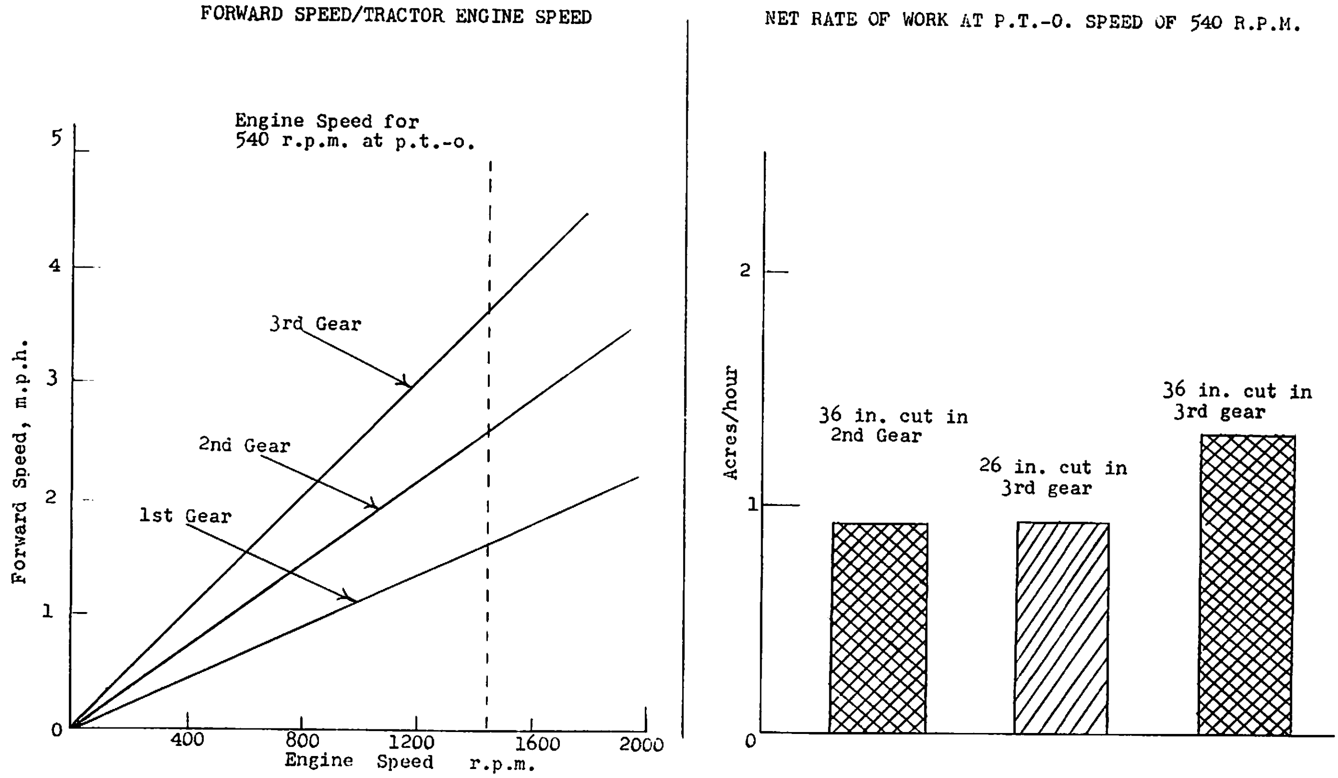


FIG. 4
EFFECT OF CHANGE OF GEAR ON NET RATE OF WORK—
TRACTOR WITH EVENLY-SPACED GEAR RATIOS

the existing medium-powered tractors (about 40 to 45 h.p. at the p.t.-o. when in work) cannot provide sufficient power. An improvement in the efficiency of present-day harvesters seems the obvious line of approach, since a considerable increase in available tractor power, the other possible approach, has certain practical disadvantages. The 40-in. flail harvesters now in production were produced initially to meet the needs of users of relatively light tractors with insufficient power to operate the larger flail machines. An increase in efficiency would allow an increase in cutting width without increased power consumption, or alternatively an increase in output for the same power consumption. This would have considerable practical advantages, particularly in lighter crops where the forward speed practicable limits the output, or when picking up from a 5-ft. mower swath. Moreover, the machines should be better able to attain a high rate of output under the adverse conditions frequently encountered in this country.

Machine Operation

In practice many farmers are not at present obtaining the best possible performance from their machines, either because of faulty machine operation or because of faults in their silage-making systems. There are certain practical points on machine operation that are frequently overlooked. For example, many users change into the next lowest gear in the thicker parts of a crop or in a crop which is just too heavy for work in the higher gear. In such cases it will often pay in terms of output to reduce the width of cut rather than change gear, since rhe steps between gears may be too high to keep the machine fully loaded by this means (Fig. 4). For some tractors the steps between gears are wider and often more unequal than in the example shown. It is a relatively simple exercise to find the amount of reduction in width of cut that is worthwhile before changing into a lower gear.

Again, it is not generally realized that an unnecessarily high mechanism speed may waste power, since with most machines the power consumed in moving air often rises disproportionately with the mechanism speed (Fig. 5). Users should experiment with their machines in each crop to determine which combination of, for example, forward speed, power take-off speed and width of cut gives the best output. Particularly where the areas to be cut are large, a relatively small increase in output can result in a considerable saving of time.

Many users have trailers that are not suitable and do not employ a satisfactory technique for changing trailers. Any saving in time when changing or emptying trailers will repay some outlay on adaptation of trailers for silage work (Table III).

Finally, the most important factor of all for efficient silage making is the use of a satisfactorily-planned and integrated silage-making system. In very many cases there is little to choose as regards performance between machines of a given size and type, but there is little doubt that the performance of machines is very frequently limited by defects in the system employed (5).

Ease of Maintenance, and Operation and Reliability

The popular types of forage harvesters are, in the main, satisfactory in these respects. However, with forage harvesters, as with many other types of machine, manufacturers still require to pay more attention to the minor details which make adjustment and operation rather easier than, at present, is often the case. The adjustments which have to be made frequently are, in general, quick and easy to carry out, but those which are made perhaps once in each field, or even once or twice in each season, are often difficult. In some cases, indeed, it is impossible for one man to carry out such an adjustment in the field unaided, and very frequently the means of adjustment is inaccessible or difficult to operate. Moreover, adjustments that are difficult to make are often neglected in practice, and the performance of a machine can therefore suffer. More attention should be paid to the problems of the user in this respect ; in many cases the modifications required should be relatively cheap and simple to carry out.

TABLE III

WEIGHTS (LB) OF CONSECUTIVE FERGUSON TRAILER LOADS IN FOUR FIELDS

Field	*N.I.A.E. Trailers With Extension Sides and Top Covers*	*Farmer's trailers without Top Cover sand Slightly Lower Sides*
1	3,844 3,822 3,682 3,518 3,314 3,452	1,812 3,108 1,803 2,685 1,663 1,597 2,994
2	5,244 4,843	3,158 3,146 3,176 3,302
3	5,310 5,334 5,720	2,736 3,284 2,992
4	5,598 5,490 5,378 5,302	3,292 3,250
Mean ..	4,657	2,750

Future Development

The long-term developments in forage-harvester design are somewhat difficult to foresee. They depend to a large extent on economic factors and also on developments in the whole technique of silage making, particularly as regards methods of improving silage quality, and of storage and feeding, and in the methods of crop and silage handling, both at the silo and at the point of feeding. Developments new to this country, such as " haylage " and " zero grazing," and also the research into factors affecting silage quality at present being carried out in many parts of the world will merit study. It is likely that, in the long term, a wider range of machine types than at present will be on the market, each suited to a particular set of farming requirements.

During the next 5 to 10 years it seems unlikely that, in general, the methods of silage making and feeding will change a great deal. Short-term developments will therefore probably be aimed at improving the efficiency of existing types of machine in order to obtain a higher output for a given power input and at overcoming some of the shortcomings of existing designs. An example of the latter is the rather unsatisfactory performance of many harvesters in small fields on relatively steep slopes. Here the use of rear-delivery machines when towing a trailer is often impracticable, often because of the occurrence of tractor wheel spin, particularly when the lighter types of tractor are used. Side-delivery machines are not a complete answer, particularly on farms where there are only either one or two tractors available. The possibilities of side- or front-mounting the cutting rotor on the tractor are worth consideration, since this would go far to overcome this problem.

Many manufacturers have explored the possibilities of using their machines for operations other than forage harvesting, for example, hay making, pasture topping and straw disposal. Some machines can also be used for light bush clearing, cutting potato haulm and loading straw left by a combine harvester into trailers. Each of the above operations presents its own problems, but each problem overcome must inevitably widen the usefulness of, and therefore the market for, a machine.

The problems of harvesting of row crops such as kale and maize are now being tackled by most manufacturers. When the various crop husbandry problems, including harvesting, are solved the latter crop is quite likely to become popular in England since it is a very high-yielding and easily-ensiled arable silage crop.

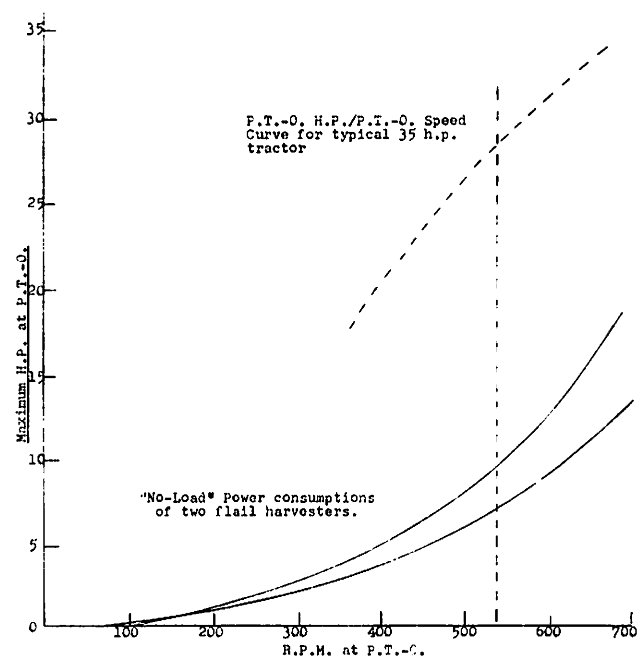


FIG. 5

POWER CONSUMPTION OF TWO 40-IN. FLAIL HARVESTERS WHEN STATIONARY AND OUT OF THE CROP (" No-Load " Power Consumption)

REFERENCES

1. BAILEY, P. H., "The Testing of Green Crop Driers." *Journ. of I.B.A.E.*, 1951, 8 (1), 15.
2. MANBY, T. C. D., "Are Official Tractor Test Results a Realistic Guide to Performance on the Farm?" *Journ. of I.B.A.E.*, 1953, 9 (3), 3.
3. MCLAREN, D. I., "Testing of Agricultural Machinery With Special Reference to Root Crop Harvesting Equipment." *Journ. of I.B.A.E.*, 1958, 14 (3), 98.
4. BAILEY, P. H., "The Measurement of Crop Drier Performance." *Journ. of I.B.A.E.*, 1959, 15 (3), 58.
5. "Methods of Making Silage With Forage Harvesters." *N.A.A.S. Tech. Report No.* 11, 1959. Ministry of Agric. and Fisheries, London.
6. HEPHERD, R. Q., AND HEBBLETHWAITE, P., "A Comparison of the Field Performance of Forage Harvester Mechanisms." *Journ.Ag.Eng.Res.*, 1959, 4 (1), 37.
7. BALCH, C. C., *et al.*, "The Effects of Chopping and Laceration Before Ensiling on the Digestibility of Silage by Cows and Steers." *J.Brit.Grassl.Soc.*, 1955, 10 (4), 326.
8. MURDOCH, J. C., *et al.*, "The Effect of Chopping, Lacerating and Wilting of Herbage on the Chemical Composition of Silage." *J.Brit.Grassl.Soc.*, 1955, 10 (2), 181.
9. DISNEY, F. J., "Investigation Into the Comparative 'Chop' Lengths of Crops Chopped by Three Types of Stationary Chopping Machines." *N.I.A.E. Tech. Memo.* 63/ATD/5 1952.
10. WIERINGA, G. W., "A Method of Assessing the Degree of Laceration by Ensiling Machines." *Landbouw. Mechanisatie*, 1958, 9 (9), 459.
11. KAPPELLE, D., AND LENIGER, H. A., "Ensiling Heavily Lacerated Green Crops." *Landbouwvoorlichting*, 1957, 14 (2), 93.
12. "Lundell 40 Forage Harvester." Test Rep. 227, *Nat.Inst. Agric.Eng.*, 1959.
13. "Wilda-Rainthorpe Sila-Masta 52." Test Rep. 202. *Nat. Inst.Agric.Eng.*, 1958.
14. "Lundell 60 Forage Harvester." Test Rep. 197, *Nat.Inst. Agric.Eng.*, 1958.
15. WOODMAN, H. E., "The Utilization of Sugar Beet By-Products." *Journ.Min.Ag.*, 1926, 33 (2), 109.
16. LANGER, R. H. M., "A Study of Growth in Swards of Timothy and Meadow Fescue," II—"The Effects of Cutting Treatments." *J.Agric.Sci.*, 1959, 52 (3), 18.

CORRESPONDENCE

6, BUCKINGHAM GATE,
LONDON, S.W.1.
21*st September*, 1960.

To the Editor.
DEAR SIR,

I read the Paper by W. H. Boshoff, which appeared in our Journal of July, 1960, with some surprise.

The object of our Institution, as I see it, is to place scientific and technical information before our membership. I can hardly think that the adaptation of the commercial bicycle can be considered a Paper of value to agricultural engineering as a whole.

The commercial bicycle was never intended by the cycle industry to be used other than as a mechanical means of transport for one or two human beings, according to the design. During my twenty years in Africa, I saw numerous instances of the bicycle as shown in the various plates included in the Paper. Any encouragement on these lines can only be considered a retrograde step. The African should be encouraged to use the "scotch" cart whenever possible. It encourages him to train his oxen, which will then be available as plough and cultivator teams. The "scotch" cart can be used for dunging the land, carrying water and the hundred-and-one odd jobs on the present-day African holding. It is easy to maintain and in many cases enjoys a substantial subsidy.

Yours faithfully,
F. D. BINGHAM.

LIBRARY ACQUISITIONS

"POWER TO PRODUCE," Year Book of Agriculture, 1960. Published by U.S. Department of Agriculture.

"SOIL EROSION BY WIND AND MEASURES FOR ITS CONTROL ON AGRICULTURAL LANDS"—Food and Agriculture Organisation of the United Nations.

"PRINCIPLES FOR BRITISH AGRICULTURAL POLICY," a Nuffield Foundation Report, edited by H. T. Williams, B.A.

"AGRICULTURAL ENGINEERING FOR EXTENSION WORKERS," by D. N. Kherdekar, B.Sc., M.I.Agr.E.

"USING CENTRIFUGAL PUMPS," by E. Allen, M.I.E.T.

"FARM MECHANISATION" DIRECTORY

A most useful addition to the Library is the eighth edition of the "Farm Mechanisation" Directory, published by Temple Press, Ltd., Bowling Green Lane, London, E.C. 1, at 37/6.

A comprehensive list of manufacturers and organisations concerned with the Industry, trade names, classified sections for various types of machines, tractor test reports, etc., are given in concise and well-indexed form.

CONTROL OF CONDITIONS IN FRUIT AND VEGETABLE STORES

by G. MANN,* A.M.I.Mech.E., A.M.I.Mar.E.

A Paper presented at an Open Meeting of the Institution of Agricultural Engineers on 11th October, 1960.

IT is not within the scope of this Paper to consider cold store construction, but it is assumed that stores will be well constructed, well insulated, and with floors of adequate strength, sufficient to support the maximum loadings—*e.g.*, the wheel loadings of loaded fork lift trucks.

Before considering the control of conditions in fresh fruit and vegetable stores, it will, no doubt, be of assistance to you in understanding the problems involved if a little time is devoted to an explanation of why certain controlled conditions are necessary. In this talk only the conditions necessary for the efficient and economical storage of fresh (living) produce will be considered ; the conditions for frozen (dead) produce are probably less complicated.

By " fresh " we mean fruit and vegetable produce which is still living ; *i.e.*, is respiring, taking in oxygen, and giving off CO_2 and producing heat. The greater the rate of respiration the shorter the period for which the produce can be preserved in a good, saleable condition.

Two factors which influence this respiration rate are temperature and the concentration of CO_2 and O_2 in the storage atmosphere. Considering, first, temperature—each commodity has an optimum temperature of storage for prolonging life. Fig. 1 shows how the storage life

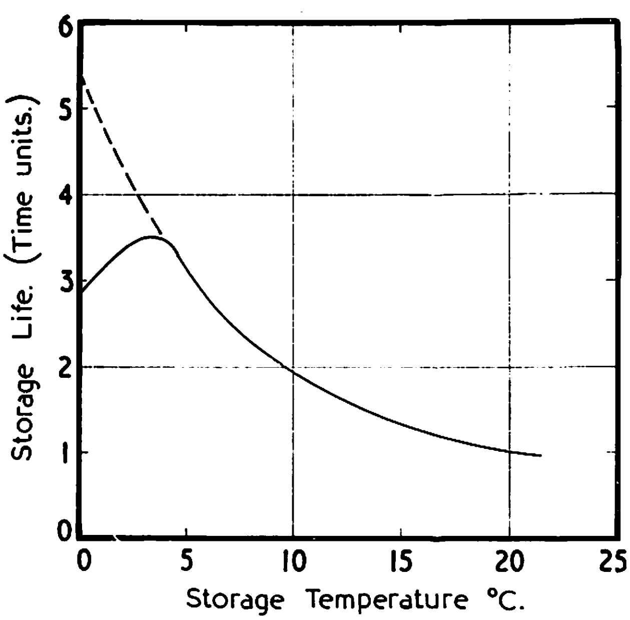


FIG. 1.
Influence of Storage Temperature on the Storage Life of Apples.

* Ditton Laboratory, Agricultural Research Council.

of Bramley apples varies with temperature. Then there is, of course, a lower limit of temperature below which the produce may suffer permanent injury. For example, bananas suffer chilling injury if kept below 54° F., and Bramley's Seedling apples are adversely affected if kept below 37° F.

A few recommended storage temperatures for fresh produce compiled from (1) and (2) are given in Table I.

The influence of the storage atmosphere is shown by the fact that Cox's Orange Pippin store best in an atmosphere of 5% CO_2, 3% O_2 and 92% N_2, Bramley's Seedling apples in 8–10% CO_2, 10–12% O_2 and 80% N_2, and Blackcurrants keep well in 25% CO_2 added to air —*i.e.*, 25% CO_2, 15% O_2 and 60% N_2. These conditions are complementary to the optimum temperature. Fig. 2

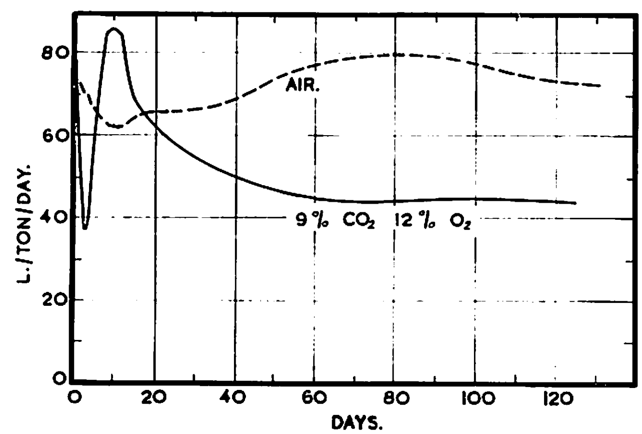


FIG. 2.
Effect of Increase in (CO_2) and Decrease in (O_2) on Respiration of King Edward VII Apples.

shows the effect of atmospheric composition on the storage life of King Edward apples. The effect of store humidity is not primarily on storage life, but on quality of the produce after storage. Low store air humidity can cause excessive water evaporation from the produce, which may not be serious in terms of loss, but may considerably decrease the quality of the fruit.

How is the produce-temperature controlled in a refrigerated store ? If the temperature of the produce is to be kept constant, the heat from three sources must be extracted continuously from the store. These sources of heat are : Heat leakage through the store structure, heat input by the air circulating fans and the heat produced by the stored produce. Heat leakage through the store structure can be reduced by efficient insulation ; heat input by the store air circulating fans cannot, in the

TABLE I

	Temp. °F.	% CO_2	% O_2	Remarks.
Apples—Cox's Orange Pippin } 92% R.H.	38/39	5	3	5 months
Bramley's Seedling	37/39	8–10	—	6 months
Newton Wonder	34	—	—	5 months
Bananas	53–57*	—	—	
Blackcurrants } 92% R.H.	32	25	—	5 weeks
Pears	29/30	—	—	3–6* months
Plums	31/34	—	—	6 weeks
Citrus—Orange } 80/85% R.H.	32/40	—	—	most varieties
Grapefruit	50	—	—	
Lemon	55	—	—	
Brussels Sprouts } 90/95% R.H.	32			2–3 weeks
Celery	32			8–10 weeks
Runner Beans	38/40			7–8 days
Broccoli	32			3 weeks
Lettuce, 90/95% R.H.	32/33			7 days

* According to variety.

initial storage, be reduced, as adequate air circulation is essential for the rapid transfer of heat from the produce to the cooler. Once optimum temperature conditions are realised, a reduction in air circulation rate (reduced fan speed) may be possible without seriously affecting the temperature distribution of the produce. The heat produced by the produce depends on the condition of the produce, its temperature and maturity ; it may be as much as 350 B.Th.U.s per ton per hour for runner-beans at 33° F., or as little as 40 B.Th.U.s per ton per hour for Bramley apples at 39° F.

When produce fresh from the field or orchard is loaded into store, the required temperature and atmospheric composition conditions should be established as soon as possible ; delay may shorten storage life. The quality of much of the produce being marketed to-day is not always first class because of the delay in reducing it quickly to the required storage temperature.

Temperature Control

If fresh produce is to be stored for several months, it is important that its temperature should be reduced to the desired level as quickly as possible (apples, 4–5 days) and held within $\pm 1°$ F. of that temperature.

The heat extracted by the refrigerating plant is the sum of the following heat quantities—the heat to cool the produce from field temperature to storage temperature, the heat leakage through the store structure, the heat produced by respiration of the produce, and the heat input by the store air circulating fans. The heaviest heat load occurs when cooling down the produce—a load several times greater than that when the produce is at the required storage temperature. The plant must, therefore, be designed for the anticipated maximum heat extraction rate ; for a 2,500 bushel apple store this is about 25,000–35,000 B.Th.U.s per hour. It is the practice to have the air cooling unit inside the store structure and to provide a fan circulating air through the produce stow, where it picks up heat and then passes over the cooler, where this heat is given up to the cooler surfaces. The rates of heat exchange from produce to air, and air to cooler, will depend on the temperature differences (air to fruit, and air to cooler) and on the rate of air circulation. The amount of air circulating is, therefore, important ; too little and the necessary heat extraction rate will not be realised without undesirably large temperature differences, and too great a rate of air circulation will be expensive in fan power. All power supplied to the fan has to be extracted as heat by the refrigerating plant. The usual rate of air circulation for a long-term produce store is about 40 changes per hour based on the empty store volume. In many installations the fan motors are two-speed, operating at full speed when the refrigerating plant is running and half-speed when it is " off." With this arrangement there is an appreciable saving in electrical power. Fans may also be reversible ; reversing the air flow occasionally can help to even produce temperatures. It is essential that the circulating air is distributed evenly through the produce stow. Fresh produce is self-heating and, therefore, if undesirable temperature variations are to be avoided, each box or tray must receive the same quantity of cool air. Until the advent of mechanical handling on pallets, the centrally-sited cooler unit provided an economic and efficient solution to the problem of uniform air distribution. Modern methods of loading a store now make it desirable to locate the cooler unit against one wall of the store, for it is difficult to manoeuvre and to stow evenly round a central obstruction. The siting of the cooler unit against one wall does, however, mean that particular attention must be given to the arrangements for air distribution by the use of air delivery ducts to ensure uniform air distribution through the whole stow. The method of stacking the produce can materially influence the distribution of cool air. If the stow is visualised as a cellular block with an air pressure differential between top and bottom, then the quantity of air flowing through a particular section will be governed by the resistance of that section. The stow should, therefore, be uniform and without breaks which would provide a short circuit path for the cooling air. It is suggested that the gap between the store walls and the produce should not be more than ¾ to 1 in. Using observed data for the resistance to air flow of a stack of fruit, it can be shown that a gap of 3 ins. between the stow and store walls would provide a short circuit path for about 50% of the circulating air—more than necessary to cope with the heat leakage through the wall surfaces. It cannot be assumed that cool air discharged directly from a unit located at one end of a store will circulate evenly through a tight stow. Such a unit, however, may be satisfactory for a store used for the short-term storage of a mixed variety of produce.

Uniform air distribution over the cooler surfaces is also very important if maximum efficiency is to be realised.

The cooler unit surfaces are generally cooled by the expansion of refrigerant (Freon) in the tubes, though in the largest installations cooling may be by circulating cold calcium chloride brine solution through the cooler coils. Where the expansion of refrigerant provides the cooling, it is important for efficiency that the refrigerant is distributed evenly through the coils and also that evaporation of the refrigerant is taking place at a suitable pressure and, therefore, temperature. Control of the cooler surface temperature of a direct expansion unit does require more careful design than a cooler which uses a secondary refrigerant at a pre-set temperature.

The Control of the Composition of the Atmosphere in "Gas" or "Controlled Atmosphere" (C.A.) Stores

For some produce—*e.g.*, Bramley apples—it is sufficient to control the produce temperature at 39° F. and the concentration of CO_2 at 9%, but for varieties such as Cox's Orange Pippin apples best results are obtained with 5% CO_2 and 3% oxygen. In both cases a first requirement is that the store interior surfaces should be lined with a material impermeable to the passage of either CO_2 or O_2; *e.g.*, metal sheets or a bituminous compound. Where only a higher level of CO_2 is required, it is sufficient to allow the CO_2 produced by produce respiration (1½–3 cu. ft./ton/day) to accumulate to the desired level, then to ventilate with fresh air (*via* 2 in. diameter pipes fitted with regulating valves) at a rate sufficient to maintain the optimum level. For example, assuming the fruit is respiring at the rate of 2 cu. ft. per ton per day, to maintain a level of 9% in the store fresh-air ventilation must be about 40 cu. ft. per hour. The actual amount of ventilation will, of course, depend on the efficiency of the store lining. Table II shows how an inefficient lining will prevent the CO_2 from building up to the desired level. With a "gas-tight" efficiency of only 0·85%, a store holding Bramleys at 39° F. would only allow the CO_2 concentration to build up to about 7%.

TABLE II

CO_2 *Production, cu. ft./ton/day.*	*Store Efficiency.*		
	0·85	0·88	0·90
1·0	5·5	7·0	8·3
1·5	8·2	10·4	12·5
2·0	11·0	14·0	16·0

Maximum per cent. concentration of CO_2 for different store efficiencies and different produce respiration rates.

An approximate "gas" efficiency figure for a store is obtained by a practical test where CO_2 is injected into the store to, initially, about a 10% level. The concentration is measured at intervals and an efficiency figure derived from the formula :

$$\text{eff} = 1 - \left(\frac{\text{cu. ft. } CO_2 \text{ escaping per day}}{\text{cu. ft. } CO_2 \text{ present}}\right)$$

Where a reduced oxygen level is required, auxiliary apparatus must be installed in addition to a gas-proof lining. This apparatus is needed to absorb CO_2. For this, solutions of caustic soda, lime or ethanolamine may be used, but a more recent development is the use of dry hydrated lime in sacks. Whatever absorbent is used, the principle of operation is the same. The CO_2 produced by produce respiration is allowed to accumulate in the store until a concentration of about 6% is reached. The air/CO_2 mixture from the store is then circulated through the scrubber unit and CO_2 is absorbed. For each cubic foot of CO_2 absorbed a cubic foot of fresh air will enter the store ; this cubic foot of air will contain only 21% of oxygen. If the store air capacity of a 2,500 bushel store is about 3,000 cubic feet (assuming 50% void), reducing the CO_2 level from 6% to 4% by scrubbing will involve removal of about 60 cubic feet of CO_2, which is replaced by 60 cubic feet of air—12 cubic feet of oxygen. By regulating the amount of scrubbing and of ventilation, the desired concentrations of CO_2 and O_2 may be controlled. The scrubber unit consists of a closed tank holding a sufficient depth of solution, and a blower operating on a closed circuit, drawing air from the store, forcing it through the solution and returning it to the store. Using lime or caustic solutions in this type of unit, it is necessary to provide drainage for the spent solution, and also means for recharging with fresh solution. A unit using ethanolamine operates on the same principle, with the difference that the solution can be regenerated by heating, and thus when once the unit is charged the solution should last for a number of seasons(5). The dry lime type of scrubber unit(6) requires a container to hold about 30 half-hundredweight bags of dry hydrated lime arranged on shelves so that the circulating air is accessible to a good proportion of the lime bag surfaces. When the lime is exhausted, it is a simple matter to remove the bags of spent lime and replace with fresh. It is usual to provide sufficient lime capacity to last for about one month. The amount of lime necessary for the absorption of a given amount of CO_2 may be calculated. This could not, however, be realised in practice, as it would mean a very large container and many bags of lime. The rate of absorption of CO_2 by lime falls off as the lime becomes exhausted, and there is possibly a degree of exhaustion beyond which it would not be desirable to go. The approximate effect of percentage exhaustion of the lime on absorption rate is given in Table III.

TABLE III

Per cent. Exhaustion.	*Store CO_2 Concentration.*		
	4%	6%	8%
0	2·5	3·2	3·8
25	0·9	1·4	1·6
50	0·4	0·75	0·95
75	0·2	0·4	0·65

Rate of absorption of CO_2 by hydrated lime in ½ cwt. bags (cu. ft./hour/½ cwt. bag).

The dry lime type of unit is cheaper in first cost than units using solutions. The running cost of a unit will vary with the price paid for lime or caustic, or for ethanolamine units the cost of electricity for regenerating.

Humidity Control

Excessive loss of weight by evaporation of water from produce stored under refrigerated conditions is one of the major causes of deterioration. While a slight loss of weight may not cause damage, and in some instances it may even be advantageous, losses of the order of 8% or more, which have been often noted, may result in a serious loss of quality, flavour and texture and a lowering in grade assessment. Fresh fruit and vegetables contain between 80 and 90% by weight of water, and much of this is easily lost by evaporation. If the relative humidity of the store air is in equilibrium with that of the surface of the fruit (97%), it cannot take up any more water, but if it is below this figure then it can take up water until it is in equilibrium with that surface. In a recent report on a survey of fruit cold stores, Rostos(3) reports evaporation weight losses varying from about 0·4% per month in a natural circulation stores to 1·8% per month in a forced circulation stores. These results clearly indicated the necessity for high relative humidity in

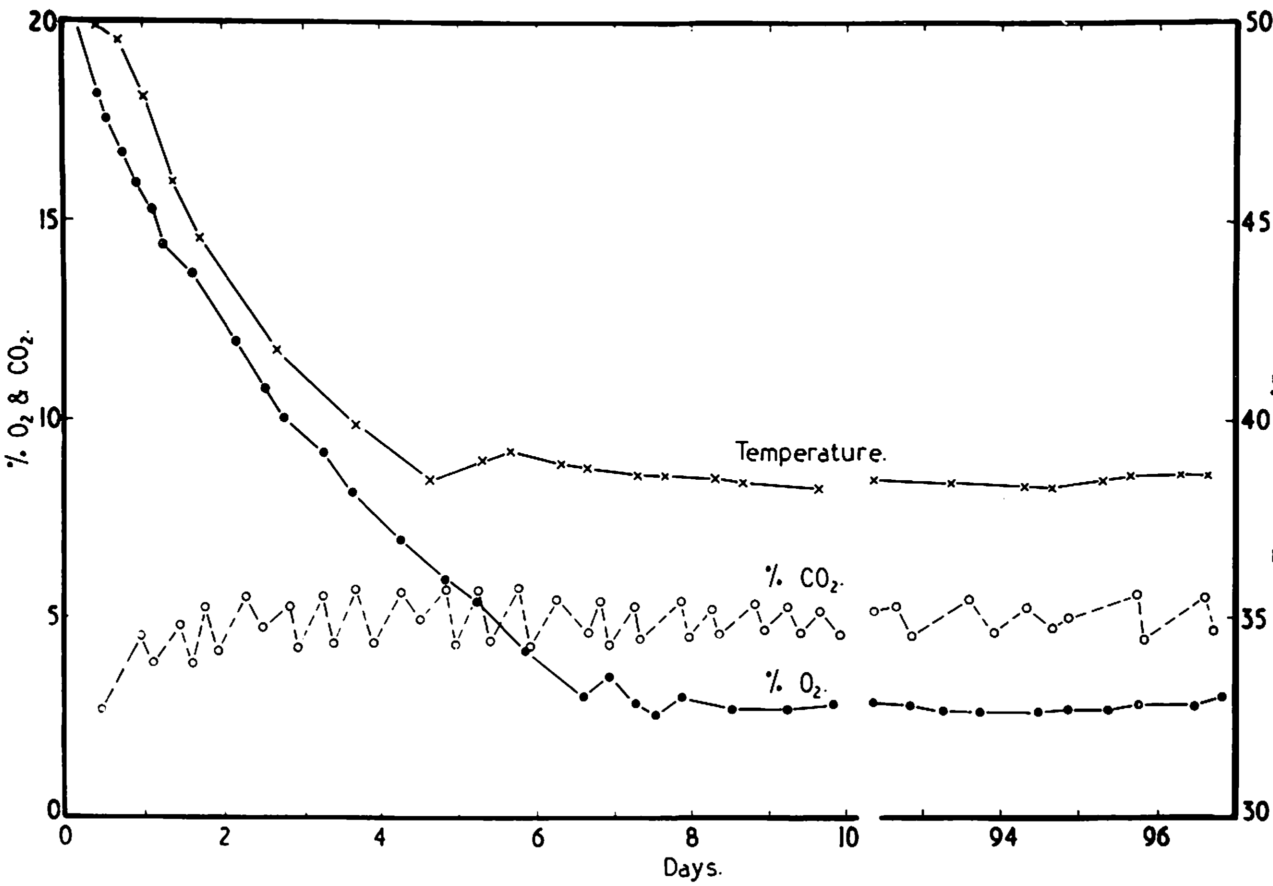


FIG. 3.
Fruit Temperature and CO_2, O_2 Concentrations in an Efficient "Gas Store."

An approximate cost per bushel stored for five months is about 5/-.

It is very important that all components of the scrubber units, including blowers or pumps, are gas-tight ; if not, leakage will prevent the O_2 level being reduced to the required value (Fig. 3).

forced circulation stores if evaporation is to be kept to a low level.

In a refrigerated fresh produce store the cooling can go through both humidifying and dehumidifying processes. If the air cooler surfaces are at a temperature below the air dew point, condensation of some moisture from the air will take place, the air being lowered in moisture content. On its passage through the produce stow the moisture content will be restored to its previous level. Under equilibrium conditions, the moisture loss of the fruit will equal the weight of moisture condensed on the cooler surfaces. It therefore follows that if the amount of moisture condensed on the cooler surfaces can be kept to a low value, the produce will benefit(4).

Two methods of controlling this weight loss are possible ; they are by restricting the load on the cooler to a minimum, thereby reducing plant running time, or by designing the cooler to effect the necessary heat transfer when operating a fraction of a degree above the desired air dew point temperature. The first aim may be achieved by restricting the heat leakage by providing more than the theoretical minimum thickness of insulation to the store structure, and by using high efficiency air term, be appreciable and more than offset the initial outlay.

The foregoing applies to new construction, but where it is desired to improve conditions in existing stores, auxiliary methods such as installing humidifying units may be considered. The humidifying unit would have to be of the type which introduces water as a fine mist into the circulating air stream. Such a method is only likely to effect a partial improvement, as much of the injected water will be collected on the refrigerated coils of the cooler unit, which will thus require more frequent defrosting. Means of defrosting the cooler surfaces is very important, particularly during the initial cooling-down period. Frost deposits on the cooler surfaces act as a thermal insulator and can seriously affect the efficiency of the cooler as a heat exchanger. The reduction in cooler efficiency will prolong the cooling of produce

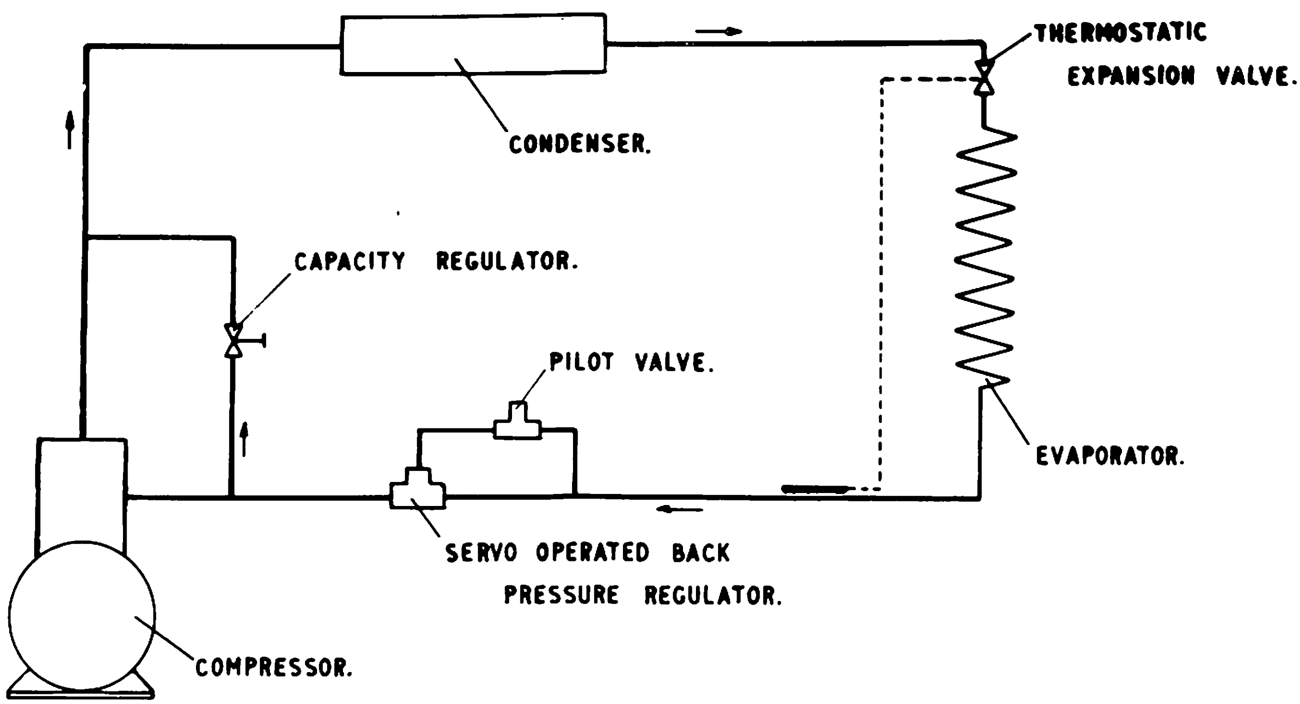


FIG. 4.
Diagrammatic Arrangement of Back-Pressure Control to Direct Expansion Cooler.

circulating fans with speed control. The design of a cooler to do the necessary cooling when operating at a mean surface temperature only 2–3° F. below mean air temperature requires a large surface area and controlled uniform refrigerant evaporation temperature. As previously mentioned, the refrigerant evaporation temperature is determined by the refrigerant pressure within the cooler coils. If, therefore, the refrigerant pressure is controlled within close limits, the cooler surface temperature may be controlled at any desired level. It is essential that this control is performed automatically by compressor speed control, or by back-pressure evaporator control. Fig. 4 shows the arrangement of a direct expansion cooler fitted with refrigerant back-pressure control. It is true that such refinements as these will increase the initial cost of the installation, but the savings resulting from improvement in quality can, in the long

and possibly be the direct cause of a deterioration of quality in the stored produce.

Instruments

The control of store air temperature is usually by a thermostat, with its sensing element located in the store. This thermostat controls the refrigeration by switching on the plant if direct expansion is used, or operating an electric control valve if the cooling system uses a secondary refrigerant—*e.g.*, calcium chloride brine. It is important that the following requirements are met : That the sensing element is located in a ventilated position, that it has a quick response to temperature changes, that the thermostat differential is not more than $\pm 1°$ F., and that it is accurate. The necessity for close control of air temperature is particularly so for pears stored at 29–30° F. ; the freezing point of pears is

28·3° F. Once a store is loaded and closed, it should not be necessary to open it again until the produce is required for the market. Accurate and reliable instrumentation of store conditions are, therefore, essential. For temperature measurement, the electrical resistance type of thermometer is the most used—not less than two elements per 2,500 bushel store. The indicators of the instruments should have an open scale which may be read with accuracy to within ¼° F.

The CO_2 concentration in a store atmosphere may be determined by direct chemical anaylsis of a sample of the store. The apparatus used for such an analysis is not entirely suitable for use in a produce packhouse, and it is usual to use an electrical instrument which gives a direct indication of the concentration of CO_2. In this type of instrument two platinum spirals are arranged as two arms of a Wheatstone bridge circuit. One of the spirals is sealed in a small chamber containing air, the other is in a chamber which can be ventilated by a sample of air drawn *via* a small pipe line from the store. Changes in CO_2 concentration will affect the temperature and therefore the resistance of the ventilated spiral, thus causing an out-of-balance current to be shown on the indicator previously calibrated in per cent. CO_2. For stores operating with a low O_2 level, the observations of concentration are made with similar instruments, with the addition of change-over valves and a small carbon furnace. The procedure is to first observe the percentage CO_2 and then to operate a change-over valve, passing the sample through a carbon furnace. In the carbon furnace the O_2 in the sample is consumed to give CO_2, the sample then passing through the chamber containing the resistance spiral. A new reading is obtained on the CO_2 indicator. Referring the two readings to a calibration chart, the correct percentage of both CO_2 and O_2* is obtained. The observations show whether scrubbing or ventilation is required.

Unfortunately, at present remote humidity measurement is not easy in a packhouse without expensive apparatus, unless one is prepared to devote some time to making observations, referring to charts or making calculations. It is, however, possible that a reasonably accurate and reliable direct indicating humidity instrument will soon be available. The sensing element of this unit is a small piece of plastic impregnated with a hygroscopic substance and having a printed circuit. In a simple electrical circuit the instrument indicates directly on a micro-ammeter calibrated in percentage relative humidity.

To summarise, a refrigerated store for fresh produce should be a sound building constructed with long-life materials, equipped with :

1. Adequate insulation with a material of low thermal conductivity which is permanent, odourless, non-hygroscopic and vermin-proof.
2. Gas-proofing which is adequate to make possible easy realisation of the required gas concentrations.
3. Sufficient refrigeration capacity to cope adequately with the maximum heat load.
4. Fans to circulate air uniformly through the produce stow, and in sufficient quantity to effect the necessary heat transfer and ensure uniform temperatures throughout the store.
5. An efficient cooler designed to operate under steady conditions at a temperature which would enable store relative humidity of about 90% to be realised.
6. Reliable automatic plant controls capable of maintaining temperatures within narrow limits.
7. Accurate and reliable instruments.

REFERENCES

(1) "Conditions of Storage of Foodstuffs," J. C. FIDLER, Ditton Laboratory Record Memorandum, No. 120.

(2) "The Storage of Vegetables," W. H. SMITH, Ditton Laboratory Interim Record, No. 36.

(3) "Survey of Fruit Cool Stores," G. M. ROSTOS, Bulletin 282, C.S.I.R., 1960, Melbourne.

(4) "The Condensation of Water on Refrigerated Surfaces," J. K. HARDY, K. C. HALES, G. MANN, Special Report, No. 54, Food Investigation, H.M.S.O., 1951.

(5) "The Use of Ethanolamine in Scrubbers for Fruit Stores," G. MANN, *Modern Refrigeration*, October, 1958.

(6) "Cold Stores for Fruit and Vegetables," G. MANN, *Agriculture*, 66, 284–9, 1959, H.M.S.O.

DISCUSSION

MR. R. HILLER (Dunnington Heath Farm) said that, unfortunately, uniform conditions were rarely achieved in the different types of commercial stores sold to the fruit grower. The average grower to whom these stores were offered knew nothing about refrigeration, and no one taught him, and he thought the refrigeration industry and agricultural engineers were at fault. No farmer would dream of buying a tractor if he did not know the performance, yet many growers would spend thousands of pounds on stores, but have not the slightest idea of their performance.

This lack of knowledge caused many inefficient stores to be built. There was a need for the refrigeration industry to understand the grower's problems and for the fruit grower to know more about refrigeration. He continued that the cost of stores was extremely high, but that suppliers were wrong to make considerable changes in specifications to reduce initial cost.

He said that time and time again stores had too small coolers, and wanted large evaporators put in in next to no time. He said that between them they must achieve a basic specification and the basic requirements of new fruit stores, and then put the results to the grower. One of the big problems facing the refrigeration industry, he added, was the question of door size. A number of growers wanted to use pallets and demanded big doors. The area of doors must be considered. Where large doors were installed, air-locks or some other method of preventing heat entering the store should be installed.

A fruit grower of any size would agree that it was absurd to have one 3-h.p. cooling unit, and it was up to

* This method may not be sufficiently accurate if practical use is made of gas mixtures containing no CO_2 and about 2% oxygen. For such an application other types of oxygen meter are needed.

engineers to find out a way of supplying extra power. He said that 3-h.p. was all right in theory, but in practice it did not always work out. Growers could not always load stores in the cool of the morning, but must sometimes do so in the heat of the evening.

He thought Mr. Mann had dealt fairly with the two main types of scrubbers—dry lime and ethanolamine. However, the cost of running these must be considered. There was no doubt that the ethanolamine type was rather expensive to run. But he asked Mr. Mann about his figures for dry lime scrubbers, because in his opinion people did not allow the lime to become 70 per cent. saturated, but changed it more frequently, thus increasing the cost of scrubbing.

Mr. Hiller pointed out that in order to keep costs of equipment down most refrigerator manufacturers were to-day fitting extended surface evaporators. With this type of cooler auxiliary de-frosting equipment was essential ; he therefore asked Mr. Mann which method of de-frosting the cooler he preferred.

DR. H. B. S. MONTGOMERY (East Malling Research Station) said that the fruit grower was showing trust in putting his produce into the store. He shut the door and left the produce until prices were right or labour was there to cope with it. And he expected to find first-class produce when he opened it again. Dr. Montgomery said that they had got to see that that trust was not misplaced.

He referred to the variation in horticultural produce. It could vary in an obvious way, as between apple and pear, or " Bramley " and " Cox," but also Cox grown in one place could differ from Cox grown somewhere else, and one season's produce could differ from another's. A variety of apple grown on grass might stand up to lower temperatures than one grown on cultivated land. This meant that the margin of safety in the prescribed storage conditions could be almost negligible for fruit grown under some conditions, and therefore that the conditions in the store must be very accurately controlled.

One of the things that wanted most attention was the question of water loss. Recalling the Australian figures of 0·4 to 1·8 per cent. weight loss per month given by Mr. Mann, Dr. Montgomery said that, taking a figure in between—say, 1 per cent.—in a crop stored for five months the loss could amount to 5 per cent. of the weight of produce. In a store holding 50 tons of Cox's Orange Pippin, worth something around £4,000, this could mean £200 lost over that period. If the grower skimped money on the design of the store he was going to lose money in this way every year he put fruit in the store. It was a betrayal of trust to encourage a grower to believe that it was cheaper to extract heat than to reduce heat leakages by efficient insulation.

He went on to mention gas tightness, saying that the problem did not arise acutely with " Bramleys." It was when scrubbing was done that, unless the store was very gas-tight, the concentrations wanted could not be achieved. He said that there was room for more research on the preservation of gas-tightness at low oxygen levels, and that there was a need for better sealing materials and better store design.

On instrumentation, he said that oxygen was measured on the same piece of equipment as CO_2. This was all right when there was a certain level of CO_2, but when there was a low concentration of oxygen and no CO_2 that instrument would not cope with it, and he wondered if there was any simple instrument that could be used. He asked what use was going to be made of the humidity indicator. The design of the store determined what the humidity would be, and little could be done after the store was built if the humidity was too low, so he advised people to chase the man who was putting it up. Dr. Montgomery also wanted to know the best place for siting this humidity indicator to secure informative readings.

Another facet of the subject to which he drew attention was that a store designed for storing apples at, say, 40° F. would not cope efficiently with the storage of pears at 29° F. He wanted to know if engineers would design a store to operate at a wide range of temperatures. He thought it should be drummed into growers that they must know what temperature ranges they wanted before the store was designed. It was his belief that the problems facing the industry in the engineering aspects of storage were so important that there was plenty of room for more research, and that more man-power was required to do it.

MR. MANN, answering Mr. Hiller's question about lime scrubbers, said that his figures were obtained from his laboratory's own tests on the absorption of bags of lime. But there were growers who tended to throw them away before it was reasonable to do so, some of them thinking : " It's time I threw that away, anyway, and got a fresh lot in." Mr. Mann thought his graph was fair, although he allowed that small local variations could occur. He added that they did not know if the lime was always of the same pH value when they got it from the merchant, and if it was not sufficiently alkaline there might be variations in absorption capacity. He had left out detailed consideration of coil defrosting on purpose because it was rather a controversial subject. He preferred the water defrost method to electric defrost operating on a time cycle, and mentioned another method —that of reversing the refrigerating cycle. But he thought these latter methods a little complicated and expensive for the simple fruit store unit.

The amount of insulation on the store was rather important. He agreed with Dr. Montgomery's remarks on gas-tight store linings, and went on that he must, unfortunately, complain about some of the materials offered. They had tested a sample which gave a store gas efficiency of 95 per cent., then a few weeks later found that there was a failure in a store using that material, and on enquiring discovered that it was no longer made. That sort of thing was going to give the industry a bad name. They were looking into the question of using sprayed-on plastic materials, or using a paper-backed aluminium metal foil, which was used quite extensively in the United States. What had to be developed was an efficient gas-proof lining, robust, and had to have a very long life—not just one of two or three years. For storage without CO_2 and with low O_2, stores have to be very gas-tight indeed. On the question of measuring oxygen levels only, he said that at the moment the cost of the instrument one could buy was about £85. This instrument made use of the paramagnetic properties of oxygen. The cost of the CO_2 and O_2 instruments was about £150. He wondered whether the Americans were not right in using direct chemical analysis, and doubted whether any firm could be persuaded to bring out an oxygen meter at a competitive price. About where the humidity indicator sensing element should be put, he pointed out that it was not going to be used all the time, and if the element was placed in the delivery air stream it would give useful information. He did not think any store was tested on construction, and suggested that humidity readings would be useful for the first season of a store, so that afterwards any defects could be rectified.

MR. E. RUSSELL (D. P. Toomey & Co., Ltd.) mentioned an example in which a proprietary gadget for increasing humidity had maintained 85 per cent. relative humidity from a previous level of 80 for storing "Worcesters." The controller was operated for about 10 minutes per day.

MR. MANN said that he was familiar with these units and had tried them out. He thought they did effect some improvement. But his feeling was that, in a way, it was a question of trying to make good a deficiency and not in a particularly efficient way. If the store had had more attention paid to the humidity angle when designed, higher humidity would have come automatically.

MR. G. P. SHIPWAY (Ministry of Agriculture, Fisheries and Food) referred to Mr. Mann's statement that cooler surface temperature should be 2 to 3° F. below store air temperature. Mr. Shipway said that he presumed that Mr. Mann had meant that coolers should be designed to operate at this small temperature difference when the produce temperature was steady and not during pull-down conditions. Often the temperature difference was considerable during pull-down.

MR. MANN replied that the three-degree figure was rather a tight one and that it could not be obtained without an extra gear attached to the refrigeration unit ; it would guarantee humidity of 92 to 95 per cent. In pull-down a temperature difference of 15 to 16 degrees was necessary to effect the high heat transfer rate required.

THE PRESIDENT said that one thing that had emerged from the discussion was the importance of better understanding between growers and manufacturers, and added that it was desirable that growers should present their problems to manufacturers and the latter should try to understand them. In engineering terms, the Institution would highlight some of the points which had been made. He said that the fruit in the shops at that moment was excellent. Growers, he continued, were now looking for higher profits and more encouragement in going on with their work.

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Hon. Secretary, E. D. Frost, A.I.Agr.E.,
East Riding Institute of Agriculture, Bishop Burton, Beverley, E. Yorks.

ELECTIONS AND TRANSFERS

Approved by Council at their Meeting on 11th October, 1960.

ELECTIONS

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Owen, R. D... .. .. Surrey

ASSOCIATE MEMBERS

Carroll, J. F. .. .. .. Hertfordshire
Vinter, J. .. .. .. Lincolnshire

Overseas

Duval, J. D. .. .. .. Mauritius
Shridharan, C. S... .. India
Smyth, H. J. W. .. .. Nigeria

ASSOCIATES

Sales, A. R. .. .. .. Midlothian
Wilkinson, W. J. T. .. Cambridgeshire

Overseas

Bush, G. J. .. .. .. Ghana

GRADUATES

Akhtar, S. .. .. .. Middlesex
Furber, C. .. .. .. Monmouthshire
Gee-Pemberton, H. W. .. Somerset
Gross, H. Z. .. .. Surrey
Plowman, N. P. .. .. Hertfordshire
Shea, M. W. .. .. Suffolk

Overseas

Millar, A. F. S. .. .. Southern Rhodesia

STUDENTS

Senior, G. D. .. .. .. Essex
Wallace, J. A. I. .. .. Cumberland

TRANSFERS

FROM ASSOCIATE MEMBER TO MEMBER

Gleadow, R. E. .. .. Westmorland
Orchard, E. W. .. .. Warwickshire

FROM ASSOCIATE TO ASSOCIATE MEMBER

Starley, A. D. .. .. Warwickshire

FROM STUDENT TO GRADUATE

Chadborn, A. G. .. .. Essex
Miller, C. N. .. .. .. Essex
Clapp, D. .. .. .. Gloucestershire

FORTHCOMING MEETINGS IN LONDON AND BRANCHES

1960

NOVEMBER 11TH

Annual Dinner, and Paper, " Various Aspects of World Developments in Agricultural Engineering as they are likely to affect this Country over the next ten or fifteen years," by C. Culpin, O.B.E., M.A., Dip.Agric. (Cantab.), M.I.Agr.E., East Anglian Branch.

NOVEMBER 14TH

" Roller Chain Drives as Applied to Agricultural and Similar Machinery," by J. B. Jackson, M.I.Mech.E., M.I.E.E., Northern Branch.

NOVEMBER 14TH

" Barn Hay Drying," by P. G. Finn-Kelcey, A.M.I.Agr.E., Western Branch.

NOVEMBER 15TH

" Mechanical Handling of Farm Materials," by J. A. C. Gibb, M.A., M.Sc., M.A.S.A.E., M.I.Agr.E.,London.

NOVEMBER 16TH

Visit to Factory of Honeywell Controls, Ltd., including a Paper, " Micro-switches—Uses Unlimited," by G. Dunachie, Scottish Branch.

NOVEMBER 23RD

Conference : " Mechanical Handling and Pre-packaging of Farm and Horticultural Produce." Papers will include " Pre-packaging of Farm Produce," by a speaker from the Produce Pre-packaging Development Association, and " Hydro-cooling—Engineering Aspects and Mechanical Handling Aspects," by a speaker from J. & E. Hall, Ltd., Dartford. East Midlands Branch.

NOVEMBER 28TH

" Machinery Requirements of Under-developed Territories," by W. Ferguson, M.Sc., A.M.I.Mech.E., M.A.S.A.E., West Midlands Branch.

DECEMBER 1ST

" Present and Future Problems in Agricultural Engineering Design, " by J. E. Bywater, M.I.Mech.E., M.I.Agr.E., South-Western Branch.

DECEMBER 12TH

" Roller Chain Drives as Applied to Agricultural and Similar Machinery," by T. N. Johnston, A.M.E.M.E., A.S.A.A., and P. J. Heyes, M.I.E.E., Northern Branch.

DECEMBER 13TH

" Reclamation of Farming Land from the Sea," by Ir. B. Prummel, London.

1961

JANUARY 2ND

" Electronic Control of Agricultural Machinery," by K. E. Morgan, B.Sc. (Wales), N.D.Agr.E., A.M.I.Agr.E., West Midlands Branch.

JANUARY 10TH

" The Mechanisation of Groundnut Harvesting," by J. C. Hawkins, B.Sc., N.D.A., and S. D. Minto, M.B.E., B.Sc. (Agric.), M.I.Agr.E., London.

JANUARY 16TH

" The Need for Safety on Farms," by J. R. Whitaker, N.D.Agr.E., A.M.I.Agr.E., and " The Part Played by the Agricultural Industry," by F. G. Hodson, F.I.M.I., M.I.Agr.E., Northern Branch.

JANUARY 18TH

" The Use of Hydraulics in Agricultural Machinery and Farm Tractors," by H. J. Nation, B.Sc. (Eng.), A.M.I.Mech.E., East Midlands Branch.

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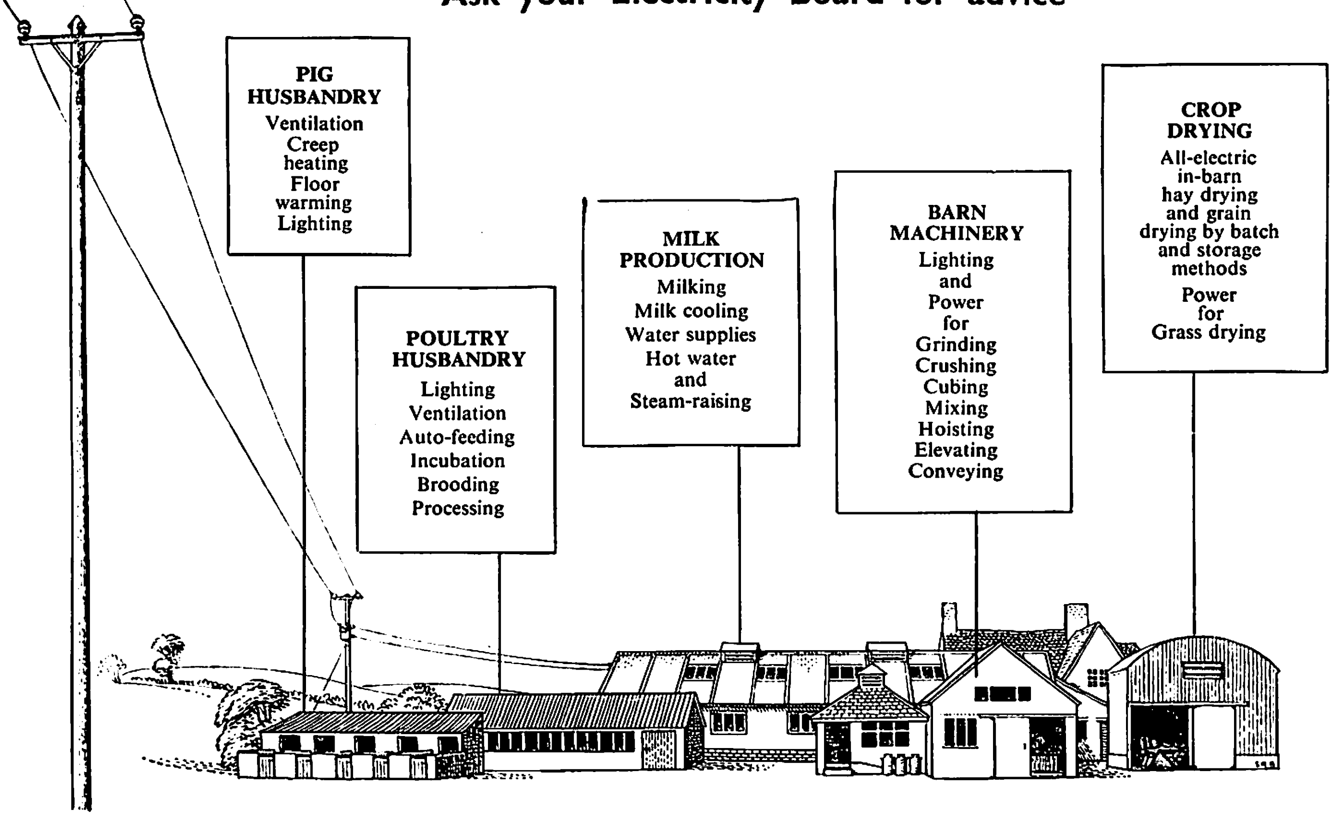

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