# THE AGRICULTURAL ENGINEER

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In this issue:

Autumn national conference:
**The waste makers**

Joint DoI/Midland Branch conference:
**Corrosion in agriculture**

# THE INSTITUTION OF AGRICULTURAL ENGINEERS ANNUAL CONFERENCE, 10 MAY 1977

To be held at The Bloomsbury Centre Hotel,
Coram Street,
Russell Square, LONDON.

On the subject of:

"PROTEIN PRODUCTION: PROBLEMS FOR THE AGRICULTURAL ENGINEER"

Registration forms for UK members are inserted in this copy of the Journal; overseas members who wish to attend should write to:

Mrs E Holden,
The Institution of Agricultural Engineers,
West End Road,
Silsoe,
Bedford MK45 4DU.

Telephone: Silsoe (0525) 61096.

# THE INSTITUTION OF AGRICULTURAL ENGINEERS, IN ASSOCIATION WITH SOUTH EASTERN BRANCH

## AUTUMN NATIONAL CONFERENCE

To be held on Tuesday, 11 October 1977 at

Writtle Agricultural College,
nr Chelmsford,
Essex

On the subject of:

"WORK DAYS FOR FIELD OPERATIONS"

Further details can be obtained from:

Mrs E Holden,
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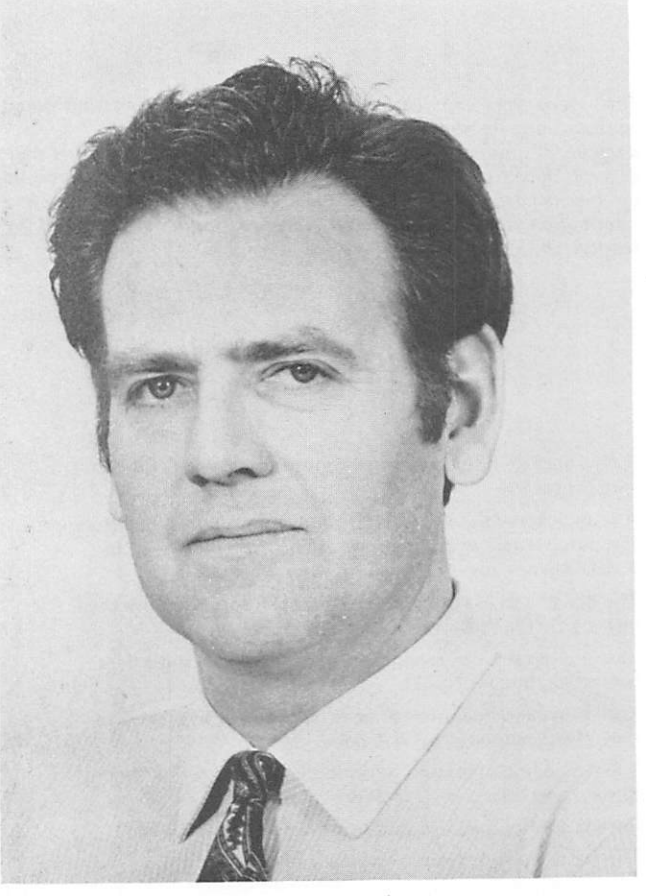
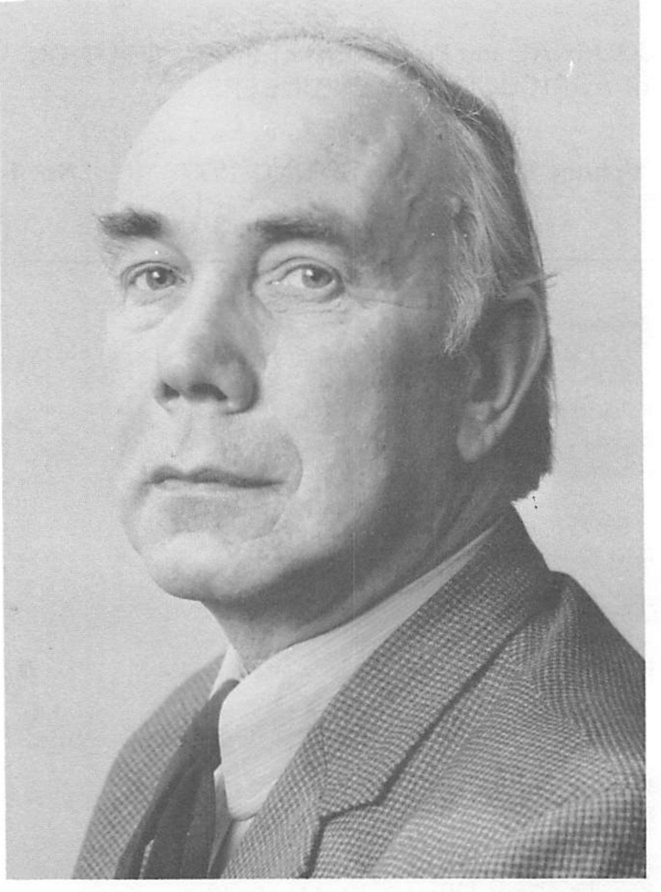
*Cover picture: Experimental potato harvester at the Scottish Institute of Agricultural Engineering.*

# A new approach to conference convention

U G Curson and J H Neville



*J H Neville*



*U G Curson*

THE Autumn National Meeting of the Institution held in Norwich last November, and which is fully reported in this issue, marks something of a milestone in the history of the IAgrE in that it was the first of what is hoped to be a long series of national conferences mounted in conjunction with branches. In making the decision some two years ago to try to organise national conferences on these lines, the Executive Committee hoped that two objectives would be achieved. First, the stimulation of branch interest in what hitherto had been exclusively a headquarters, activity and, secondly, the spreading of the load of conference organisation since, alongside the decision to ask branches to help, went the desire to step up the level of activity from two to three national conferences each year.

The East Anglian Branch was the first to offer its services. This proved a happy first choice since the Branch has a long tradition of one-day autumn conferences which have a steady following among the agricultural engineering and agricultural communities in the area.

The replacement of the normal branch autumn conference by a national event inevitably affected the type of attendance and atmosphere of the conference. However, the subject chosen by the local committee and endorsed by the Executive was one which was of considerable interest and importance to the agriculture of the area and one which could well have been chosen for a branch conference.

The objective of "The Waste Makers" was to review the type and size of loss incurred in the mechanical harvesting and storage of a group of arable crops which is of major importance in East Anglia. The main themes of the speakers were, firstly, the large overall size of crop losses in cash terms and secondly, their variability due to such factors as weather, soil type, degree of maturity, the quality of the harvesting machinery itself and the men operating it.

Abundant evidence of the size and sources of loss is available from the detailed work of the Agricultural Development & Advisory Service and of the bodies associated with particular crops such as the British Sugar Corporation and the Potato Marketing Board. The data readily point to the crops where there is greatest scope for improvement. Root crops appear to be the most vulnerable to harvesting and storage losses; in grain crops the situation is much better given normal working conditions.

For the agricultural engineering industry there would appear to be three lines of approach in trying to bring about further reductions in harvesting losses, each with its own time scale. The aspect which could bring the greatest short term benefits is the training of a larger proportion of machinery operators to bring them nearer the standards of the best. In the medium term should come the development of more efficient machinery, using the results of current research into the design and performance of individual components of the harvester, the monitoring of its performance and ease of control by the operator. In the long term is required the establishment of research into revised methods of harvesting in an endeavour to overcome some of the main drawbacks of the current ranges of machinery: attention should be paid to the lifting of excessive quantities of soil by most harvesting machinery and the separation of this from the crop we require.

The size and value of current crop losses surely mean that funds must be made available for tackling all three approaches to the problem.

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*J H Neville is Registrar, National College of Agricultural Engineering, Silsoe.*

# A statistical review of harvesting and storage losses in cereals and pulses, sugar beet, potatoes, vining peas and beans


## T W D Theophilus BSc (Hons)


THE main purpose of this paper is to make a statistical review of the losses incurred in the harvesting and storage of the main crops grown in the UK, ie cereals, sugar beet, potatoes, vining peas, dried peas and beans. The importance of these crops in terms of land utilisation and their contribution in terms of output can be seen from the following figures.

1975/76 (provisional)

| | '000s hectares | '000s acres | Output £ million |
|---|---|---|---|
| Cereals | 3651 | 9023 | 602 |
| Potatoes | 204 | 503 | 403 |
| Sugar beet | 197 | 488 | 87 |
| Peas (vining and dried) | 83 | 199 | 35 |
| Beans (stockfeed) | 62.5 | 150 | 13 |
| Total | 4197.5 | 10363 | 1140 |
| Total tillage (IK) | 4814 | 11896 | 1686 |
| Total agricultural acreage (UK) | 18985 | 46913 | 5054 |

Livestock and livestock products contribute the major proportion of the total output of agriculture (66%). However, the crops under review account for over 67% of the total output of all crops (including horticulture). The above returns were achieved after incurring losses in harvesting and storage. There is no doubt that these losses are considerable and if minimised the individual farmer would derive financial advantages and the nation's balance of payments would also benefit.

The losses incurred are the result of a number of causes. Physical losses are the most obvious and perhaps they are the easiest to control and rectify. These physical losses vary from losses of grain due to poor setting and driving of combine harvesters, to potatoes and sugar beet left in the ground unharvested. In addition losses are incurred due to damage during harvesting and through handling; this is extremely prevalent in potato crops.

For most agricultural crops a timeliness cost is incurred. Timeliness is the ability to perform an activity at such a time that the quality and quantity of the product are optimised. Timeliness cost is the loss of value of a product due to the lack of timeliness. A timeliness cost may be incurred if the operation is carried out over an extended period of time. For example as a cereal crop matures, the dry matter yield increases. However, at some point, overall crop yield declines through senescence and then shedding and other losses. It must be remembered that crop losses may never be zero as most operations involve some losses. For example, combine harvesting results in some cutter bar and threshing losses regardless of the timing of the operation.

Further losses are incurred amongst those crops that are stored for a period of time, eg cereals and potatoes. Losses are the result of shrinkage, respiration, pests and mechanical damage, disease or a combination of these.


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*Paper presented at the Autumn National Conference of The Institution of Agricultural Engineers, at Hotel Norwich, Boundary Road, Norwich, on 9 November 1976.*


The magnitude of these crop losses is considerable and it is doubtful whether the agricultural industry as a whole is aware of their significance in economic terms. An assessment of the physical and financial losses of each crop under review has been made in order to measure the scope of the problem and to see the likely savings and returns that could be obtained if the scale of these losses could be minimised.

## Sugar beet

Physical losses are a major problem in sugar beet production. This is due mainly to a relatively high percentage of the crop being left unharvested on the surface and in the ground. A British Sugar Corporation survey in 1973 showed that on average 3.16 tonnes/hectare (1.26 tons/acre) were left unharvested. Of this 40% consisted of surface losses. The range of losses was wide and in one case 17.5 tonnes/hectare (7 tons/acre) was found in the ground. Thirty two per cent of the fields had losses exceeding 3.14 tonnes/hectare (1.25 tons/acre) and in fact averaged a total loss of 6.03 tonnes/hectare (2.4 tons/acre). The survey also showed that crops drilled to a stand averaged losses of 4.00 tonnes/hectare (1.60 tons/acre).

The main reasons put forward for these losses were blunt knives, poor driving and bad machine setting. Speed of operation was seldom blamed for loss. Soil condition had some effect, moist soil giving lowest losses, and very wet or very dry soil higher losses.

The implication of these losses for the average producer, who grows 11.5 hectares (28.3 acres) of sugar beet, is that 36.3 tonnes (35.65 tons) of saleable beet never reached the factory. With beet at £18.94/tonne (£19.28/ton) this means a financial loss to the average grower of £687 (less transport cost). The situation would be exacerbated where losses are higher.

If we look at the national picture and consider the elimination of all physical waste, this would result in a saving of 624 749 tonnes (614 880 tons) of saleable beet or about £12 million. In terms of area used, assuming an average yield of 39.36 tonnes/hectare (15.68 tons/acre), this is equivalent to 15 870 hectares (39 214 acres). In practice it is highly unlikely that all losses can be eliminated, but even a small saving will improve the financial affairs of the farming industry and the nation's balance of payments. If a ten per cent reduction in losses were achieved an additional 62 475 tonnes (61 488 tons) of beet would be available for processing (in financial terms this means an additional £1 185 500 approx to producers, less the cost of transport).

The saving in terms of imports, assuming that the production of raw sugar is 5.77 tonnes/hectare (2.3 tons/acre), would be in the region of 91 640 tonnes (90 192 tons) if all losses were eliminated. Thus for each ten per cent saved, imports could be reduced by say 9 144 tonnes (9000 tons) which at £149.5/tonne (£152/ton) (ACP guarantee price) gives a possible saving of £1.37 million. If it were possible to cut out all physical losses our import bill for sugar could be reduced by £13.7 million.

The timeliness cost as far as sugar beet is concerned is complicated by external factors which have little to do with the production of the crop "per se".

A grower may expect an average crop with adequate soil moisture to increase yield by 6.27 tonnes/hectare (2.5 tons/acre) of roots in October and by 2.51 tonnes/hectare (1 ton/acre) in November at constant sugar percentage. If the yields do increase as suggested then, other things being equal, the farmer could raise his yields by delaying harvesting. However, the opportunity cost of delaying the harvesting of beet can be considerable. The delay could coincide with deterioration in weather conditions thus increasing the cost of harvesting, and due to adverse conditions the level of losses could increase. Also the delay could result in the late sowing of winter wheat, or perhaps the impossibility of sowing winter wheat. Late November sowing of winter wheat compared with mid-October could result in yield reduction of 305 kg to 550 kg/hectare (2.5 cwt to 4.5 cwt/acre). The substitution of spring barley because of the inability to sow winter wheat will result in a profit reduction of £49/hectare (£20/acre).

The other difficulty facing farmers who wish to maximise the yield of sugar beet is the demands set by the British Sugar Corporation to have an even flow of beet to keep their factories going during the campaign period.

Sugar beet as a crop is not stored for long periods. To enable winter wheat to be sown at near the optimum time, farmers may harvest their beet early and store the crop in clamps. This could lead to a small loss of sugar. Work done by Martens and Oldfield would indicate that the average storage period during harvest was 18 days and that the maximum amount in storage was 25%. The average loss was 147 grammes sugar beet per tonne per day (150 grammes sugar beet per ton per day), thus the loss for the average 18 day storage period is 2657 grammes/tonne (2700 grammes/ton). The estimated loss of raw sugar due to storage is in the region of 5080 tonnes (5000 tons).

## Potatoes

During a normal year approximately 6.32 million tonnes (6.2 million tons) of potatoes are produced, although last year this figure dropped to 4.27 million tonnes (4.2 million tons); 203 557 hectare (503 000 acres) of potatoes are grown of which 173 610 hectares (429 000 acres) are devoted to the production of main crop with an average yield of 32.6 tonnes/hectare (13 tons/acre).

In the harvesting of potatoes the losses fall into two categories. Firstly, losses due to sound potatoes left in the ground. Secondly, potatoes damaged by the lifting operation. Severely damaged potatoes are unsaleable and their value can be charged as a harvesting cost.

### Ground losses

Potato Marketing Board surveys indicated crop losses due to potatoes left in the ground of 3.1 to 9.2%. With an average loss of 6% this is equivalent to a reduction in yield harvested of approximately 1.80 tonnes/hectare (15 cwt of potatoes/acre). To the grower this is a loss in output of at least £74/hectare (£30/acre) assuming potatoes are fetching £39.37/tonne (£40/ton). With higher prices the losses would be increased accordingly.

### Crop damage

Along with the crop losses there will be those due to crop damage. The range of losses due to severe damage were 778 kg to 1.845 kg/hectare (6.2 cwt to 14.7 cwt/acre) giving an average loss of 1506 kg/hectare (12 cwt/acre). In value terms at £39.37/tonne (£40/ton), this amounts to a reduction of £59.3/hectare (£24/acre). The total losses, which amount to 10.4% from both sources, is enormous. If all potatoes were lifted and all severe damage was eliminated, an additional 3.39 tonnes/hectare (1.35 tons/acre) of ware potatoes would be available for sale. From the national point of view this would be an additional 588 293 tonnes (579 000 tons) of ware potatoes. The total value of this loss at £39.36/tonne (£40/ton) is approximately £23 million. Under normal conditions it is doubtful whether the additional potatoes harvested would meet an effective demand from the consumers. An increased supply of 588 293 tonnes (579 000 tons) would cause a glut if the acreage grown was kept static and average yields produced. If these losses were completely eliminated it would be possible to reduce the area of potatoes grown by approximately 18 211 hectares (45 000 acres). The land set free could be used for the production of any other crop whilst achieving enhanced profit margins from a smaller acreage of potatoes. Assuming a 10% reduction in losses from the national potato crop, 1822 hectares (4500 acres) could be set free for the production of alternative crops.

### Storage losses

As far as storage of potatoes is concerned there is a decrease in returns from the loss of ware potatoes. Store losses can be of three kinds; first an actual weight loss in the quantity of stored potatoes (shrinkage), second physical damage, third disease which results in a lowering of the ware percentage. Shrinkage results from respiration, evaporation and sprout growth.

### Damage

Serious damage makes a potato unfit for human consumption; it may be a complete loss or usable for stockfeed only. Any damage can allow the spread of disease and so increase indirectly the amount of stockfeed and rotten potatoes. Damage occurs mostly during harvesting but also during loading and unloading of the stores and so is largely independent of storage period or method of store management.

### Disease

Rotting diseases make potatoes unfit even for stockfeed and so they represent a complete loss to the producer. Widespread development of rotting diseases can also reduce the expected increase in returns by forcing the farmer to empty his store earlier than planned even if prices are unsatisfactory. If only those potatoes in good condition are stored for a long time under good store management there should be little risk of serious development of rotting disease, especially if refrigeration is used.

Experience at Sutton Bridge suggests that damage and disease probably cause a loss in ware percentage of about 5% in potatoes stored in reasonably good condition and with good store management. This figure would be affected very little by the length of storage but could increase markedly if care is not taken to minimise damage. When there is a widespread development of rotting diseases, disastrous losses of 10–20% or more can occur and these will increase with time unless the spread of disease is checked.

Combining these ware losses from shrinkage damage and disease gives an expected minimum fall in ware percentage of 6 to 7% in potatoes stored until the beginning of January and a probable total fall of between 10% and 15% for potatoes in good condition stored until March and later.

Assuming that the main crop will be in the region of 5 million tonnes, it is estimated the amount stored for any length of time will be approximately 4 million tonnes, about 50% up to the end of January and the balance until the end of the season. The estimated loss of ware potatoes would be approximately 300 000 tonnes plus some stockfeed potatoes. The loss in financial terms is approximately £12 million. If the loss in storage could be completely eliminated, which unfortunately is not possible, the savings would enable the national potato acreage to be reduced by a further 9308 hectares (23 000 acres). A complete elimination of all losses from both harvesting and storage causes would be worth £35 million to the industry. However, it is doubtful whether a market could be found for the additional supply of potatoes. The saving would enable the potato acreage to be reduced by 27 519 hectares (68 000 acres) and the land devoted to other uses, a reduction of 13.5% in the potato area. As the complete elimination of losses is a practical impossibility, it would be more realistic to see what savings could be achieved from marginal reduction in losses. A ten per cent reduction in the losses incurred would enable the national potato area grown to be reduced by 2753 hectares (6800 acres). In the case of the average farmer a 10% reduction in losses would increase his sales/hectare by £19.77 (£8 per acre), this is a modest target which is well within the capability of practically every farmer.

The gross output from a hectare of potatoes can be over five times that from barley and one might expect the individual farmer to go to great lengths to exploit the full potential of the potato crop: also the sugar beet crop. As far as crop losses are concerned the reverse appears to be the case. Loss of grain from the combine has received wide publicity and many farmers show concern when threshing losses exceed 62.7 kg/hectare (56 lb/acre) which represents only 1 to 2% of the yield, the value of which is about £1.75. Potato harvester studies have revealed losses and severe damage of over 10% in the majority of cases and the value of these losses is over £123.55/hectare (£50/acre). In the case of sugar beet the value is about £61.78/hectare (£25/acre). In view of the lack of concern about losses in the potato and sugar beet crops it is probable that very few farmers are aware of their magnitude.

## Cereals

An investigation into cereal losses was carried out by ADAS Mechanisation Department. The loss of grain in cereals is due to threshing losses, shedding and header losses. The threshing loss is up to 56.0 kg/hectare (50 lb/acre) of which 20% occurs at the drum, 20% at the sieve loss and 60% is walker loss.

Shedding loss on the whole was negligible although the investigation recorded a few cases of severe shedding. On average the loss from this cause was barley 8.98 kg/hectare (8 lb/acre) and wheat 5.60 kg/hectare (5 lb/acre).

Header losses in barley at 94 kg/hectare (84 lb/acre) were twice those in wheat. The variety and date of cutting appear to have a considerable influence on this problem and the penalty for leaving barley for an extra two weeks may be up to 376.6 kg/hectare (3 cwt/acre). Merely extending the use of a machine to deal with more acres at the end of the season could result in high header losses. Any improvement in the general level of utilisation of combines must clearly come from other less risky actions, eg driving the machine faster for the same length of time. Another is to start combining earlier and to accept that drying will be essential. An early start to the harvest should minimise the risk of over mature crops which are susceptible to shedding and header loss.

The estimated losses from the above causes are approximately:

| | Wheat | | Barley | | Other cereals | |
|---|---|---|---|---|---|---|
| | /ha | /acre | /ha | /acre | /ha | /acre |
| | kg | lb | kg | lb | kg | lb |
| Threshing losses | 56 | 50 | 56 | 50 | 56 | 50 |
| Header losses | 47 | 42 | 94 | 84 | 62 ) | 55 ) |
| Shedding losses | 5.6 | 5 | 9 | 8 | | |
| | 108.6 | 97 | 159 | 142 | 118 | 105 |

On a national scale the losses are:

| | | |
|---|---|---|
| Wheat total loss from | 1 033 973 hectare | = 112 416 tonne |
| | (2 555 000 acre | = 110 640 ton) |
| Barley total loss from | 2 343 133 hectare | = 372 935 tonne |
| | (5 790 000 acre | = 367 044 ton) |
| Other cereals total loss from | 274 377 hectare | = 32 289 tonne |
| | (678 000 acre | = 31 781 ton) |
| Total | | 517 640 tonne |
| | | (509 465 ton) |

Total value of grain losses at 68.88/tonne (£70/ton) is £35 662 500, and a saving of only 10% represents an additional £3.5 million to the industry.

In addition to the aforementioned losses, storage losses are incurred. These losses are due to the loss of weight incurred in storing and also due to vermin damage. The size of the losses are not very great at about 1½ to 2½ % of the weight put into store. Assuming that about 10 to 12 million tonnes are stored for any length of time, the estimated loss of grain is approximately 175 000 to 200 000 tonnes depending on amount stored. The value of this to the industry is about £12 to £14 million. The scope for any significant saving in this sphere is very limited.

## Peas and beans

Approximately 52 205 hectares (129 000 acres) of vining peas are grown in the United Kingdom. The amount of investigation into harvesting losses incurred in the crop has been very little and limited to Humberside and the Eastern Region by ADAS. However, it is obvious from the little work carried out that the losses vary considerably. There are obviously many factors contributing to the losses but the most significant by far seem to be weather conditions. Timeliness of operation when harvesting is of paramount importance as far as this crop is concerned, any delay could materially affect the quality of the crop with the consequential reduction in returns. Generally speaking the objective of the producer is to get the crop off as quickly as possible, without paying too much attention to maximising the yield. In addition pressures are put on the farmer by the processor to get the peas in to meet the demands of the factory which processes the product.

An investigation by ADAS showed a range of losses between 410 kg and 1463 kg/hectare (3.25 cwt and 11.66 cwt/acre). The average losses appear to be about 659 kg/hectare (5.25 cwt/acre). The value of this to the industry is about £4.4 million.

The acreage of dried peas is approximately 28 733 hectares (71 000 acres), producing 3.01 tonne/hectare (24 cwt/acre) of harvested peas. The Agronomy Department of ADAS Eastern Region carried out an investigation into harvesting losses in this crop. The results showed a staggering loss of unharvested peas and pods amounting to 1004 kg/hectare (8 cwt of peas/acre). The losses were due to pods lying on the ground with fungus growth causing considerable losses. In addition a further 1004 kg/hectare (8 cwt/acre) (33%) of the harvested crop were stained and consequently could not command highest prices in the market. The value of the losses to the industry is in the region of £3.5 million. Harvesting and drying techniques involving harvesting at about 45% moisture content have been developed to eliminate largely the loss and staining problem but they have yet to be widely adopted by growers.

## Beans

Approximately 60 703 hectares (150 000 acres) of beans are grown annually for stockfeed. Again very little work has been undertaken regarding losses during harvesting. From observation work by agronomists, it is said that the losses incurred are relatively small at approximately 125 kg/hectare (one cwt/acre). The value of the losses at current prices is in the region of £750 000.

## Conclusions

The estimated value of the losses incurred is enormous and amounts to £106 million. The value of the losses is approximately 9% of the output of the crops reviewed.

**Summary of estimated losses**

| | Harvesting £ million | Storage £ million |
|---|---|---|
| Cereals | 35.70 | 14.00 |
| Potatoes | 23.10 | 12.00 |
| Sugar beet | 12.00 | .76 |
| Vining peas | 4.40 | |
| Dried peas | 3.50 | |
| Beans | .75 | |
| | 79.45 | 26.76 |

The elimination of all the losses would increase the national farming net income by 7.8%. Incomes on arable farms would benefit considerably more as practically the whole value of the losses saved would be clear profit. The effect of eliminating the losses on mainly cereal farms would be to increase net farm income by £9.9/hectare (£4/acre), and in the case of intensive arable farms, the level of income would be increased by £28.16/hectare (£11.4/acre).

The total elimination of all losses is highly unlikely and in fact could be too costly as the marginal costs would be greater than the returns that would be obtained. However, there is no doubt that considerable reduction in the level of losses can be achieved to the advantage of both the agricultural industry and the nation as a whole. With only a 10% reduction in losses a saving of over £10 million is possible. Any reduction in losses will help the agricultural industry to achieve the targets set out in the White Paper — "Food From Our Own Resources".

The reduction in the level of losses incurred by the sugar beet producers will help the nation as well as the individual farmer. As far as the potato crop is concerned reducing the losses in harvesting and storage will enable the grower to increase his profits per acre. As far as the nation is concerned the acreage devoted to potato production could be reduced. With a 100% saving, approximately 27 519 hectares (68 000 acres) now producing potatoes could be used for an alternative crop. With only a 10% reduction in waste 2753 hectares (6800 acres) of land could be used for producing alternative crops instead of potatoes.

# The design and use of combine harvesters for minimum crop loss

Dr Ing W Busse

## Introduction

THE Conference objectives are covering the size and types of crop losses and the means to minimise them. How differently the problem of losses can be considered may be shown by the following short story:-

At the turn of the century a smallholder ploughed his soil with a cow-drawn-plough. His wealthy neighbour pointed out that the cows would give much less milk by doing so, and therefore he would have a loss. The smallholder answered: This is true, but still my cows give more milk than your oxen.

This remark shows very clearly how important it is to define the size and the types of losses in comparison with the %, which would be desirable. The discussion about the acceptable size of losses will never stop. All important improvements in design have been found on the way to "minimising losses".

On the other hand, we always have to keep in mind that each precaution of minimising losses is only significant as long as the value of the saved grain is higher than the cost of the saving action.

Now the necessary definitions: The combine harvester collects grain and "Materials Other than Grain". called M O G ie straw and chaff. Here we understand loss as grain only, not of MOG, though the price of straw is rather high this year. We also tend to overlook the losses of grain occurring ahead of the combine — losses by wind, animals, lack of pest control, or by unsuitable varieties of crop.

## The types of crop losses in connection with the design of a combine harvester

First of all the design has to provide all necessary means to minimise crop losses.

### Head losses

There are different types of cutting heads: the common cutting head for small grain, the pick-up heads for swath harvesting and special heads for maize and other special crops. Losses at the cutting head are usually very low (0.1 to 0.2%). Over the years we learned to pick up even long, damp, weedy and laid crops. The distance between the fingers and the centre line of the cross auger, the shape of the bottom of the trough, the suspension, the type and shape of grain lifter, the diameter of the reel, the number of reel arms, the control of the reel fingers, the reel speed related to the ground and to the machine, the knife speed, the diameter and the pitch of the cross auger, the design of the fingers in the cross auger, which feed the material into the elevator: all these factors and their relationships are important, in order to make sure that the ripe crop is cut and fed evenly into the elevator.

It is not only important, that the grain does get into the inclined elevator, but also how it gets into it, because the distribution influences the efficiency of the entire machine, so that the head is of outstanding importance. With the exception, for example, of lost ears in very short straw in front of the cutterbar, which are almost unavoidable, there are no losses in the grain cutterbar.

The grain cutterbar is most important in the UK, indeed, but for the sake of completeness, we have to mention a few special models to the current trend, which also serve the purpose of avoiding losses. There are, for example, short lip headers with a shorter distance between knife and centre line of the cross auger in combination with smaller diameter reel especially suitable for rice and soya beans. While the varieties of soya beans in South America are cut with the common long lip header, in North America short lip headers usually are equipped with the so called flexible floating cutterbar. This device cuts the header losses in soya beans down by 50%, from ie 10% to 5%, and the farmers pay for this special equipment. There are other special heads available which cost about £2,500 for a four row head. this is said to save another 50%, which means it leaves 2.5% cutting losses.

While the farmer is prepared to pay for the flexible floating attachment, we have to wait and see if in their opinion the investment for a special head is economical.

Also to be mentioned is special equipment for the cutting bar in rape. To minimise losses the farmer has the choice between pick up threshing and direct cutting. Pick up threshing leads to a reduction of head losses, but also to a reduction of yield. The direct cut, with special equipment, increases the head losses but it requires one working stage less and it also increases the yield by the full ripeness, at the same time with an increased risk of shedding losses. Here is to be seen no clear trend, because apparently there are still other economic influences which take part.

We also have to mention that at the present we are working to find a possibility to mechanise sesame seed harvest. With the normal head the cutting losses amount to 50% of the total yield since the pods of the sesame fruit burst with the slightest contact of the stalk and the desirable touchless cutter has yet to be invented. But we are very confident that soon we can offer something suitable for the sesame harvest, which is important especially for some developing countries. The picking units for the maize grain harvest, special equipment for sorghum, and others which are important outside the UK, may only be mentioned.

### Threshing losses

Threshing losses in cereals are avoided by correct adjustment of cylinder speed and concave setting. Today's design of concave and cylinder speed adjustment from the driver's platform makes the use very easy and does not need to be discussed further. We must emphasise the importance of the separation of the kernels through the concave, which should be maximum, in order to load the walker as little as possible. In gaining this objective, we have included all the precautions in the threshing unit.

I would like to mention a few influencing factors like the radius of the concave in relation to the radius of the cylinder, the shape and arrangement of the cylinder bars, the position of the upper elevator shaft, the adjustability of the concave in the front and in the rear with two or one control levers. All these details have great influence on the grain separation and breakage.

To minimise losses of rice the peg tooth equipment became standard. The kernels are stripped off the ears in such a way that the skin is not damaged, otherwise it becomes yellowish, which means loss of value because the faultless white rice gets a better price.

To minimise threshing losses in clover seeds, concave filler plates are installed. No other change is required for threshing clover seed with a normal cereal machine.

For threshing grain maize, cylinder filler plates are installed between the bars, so that no cob can pass unthreshed and therefore cannot lead to losses.

Only to improve concave separation in some Scandinavian conditions other concaves with wider spacings are required. In dry conditions where the grain maize is really ripe, the standard concave can be used for small grain and grain maize as well.

Where does the current trend of threshing go? Well, there is still no new trend noticeable.

There is a development published in the USA where the old sheller principle — well known from the so-called corn-pickers — is used. Two rotors are arranged parallel to each other lengthwise in the machine. They exceed a length of 7 feet and take over the function of the threshing elements and that of the walker. It is said that the machine has gone into serial production this year. It is

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known that the machine is different in function and more expensive than conventional machines. It is also said that the higher costs can be paid off with maize and soya beans, but not with grain. Consequently this system will not be important for Europe.

**Walker losses**

Walker losses are the most important losses on today's combines. Some walker losses are unavoidable, since it is practically and economically impossible to separate the last kernels out of the straw. The bigger the straw mass, the more kernels stay in it.

It is shown in the diagram "Walker losses versus throughput". From this diagram we may derive three results.

(a) Before talking about the throughput of a combine you have to decide which amount of losses you consider as reasonable. In the western world total losses of 0.5 to 1.5% are considered as acceptable. As the sievepan losses usually amount only to about 0.2%, walker losses of 1.0% are reasonable. At this point our diagram shows a throughput of 23 t/h. With a cutting width of 5.1 m and a crop yield of 6 t/ha this means a forward speed of 7.7 km/h.

(b) In order to reduce the walker losses down to 0.5% the operator has only to reduce the forward speed down to 5.8 km/h. Then he gets a throughput of 17.5 t/h (instead of the 23 t/h at 1%). Thus, slowing down the forward speed is an effective means of minimising losses "by use". This way, however, is not very economic as shown by the following calculation.

If the price of 1 tonne of grain is £90 and the yield is 6.25 t/ha (2.5 ton/acre), then the value of 0.5% saved grain is £2.8/ha (£1.1/acre). On the other hand the harvesting costs may be £30/hectare (£12/acre) on the basis of 1% losses. To reduce the losses down to 0.5% you have to decrease the throughput from 23 down to 17.5 t/h, ie by 24%. About by the same relation you increase harvesting costs, that is from £30/ha (£12/acre) to £39.3/ha (£15.7/acre). The increase is £9.3/ha (£3.7/acre). By saving 0.5% grain you in fact lose £6.6/ha (£2.6/acre) by increasing harvesting costs. This really is a poor business. There is of course a point where both sides of the equation are equal.

(c) The third result which can be read from the diagram, is the fact that a reduction of losses by design can be very effective. If under given field conditions and with given forward speed the losses can be reduced from 1% to about 0.45%, such a reduction means an increase of throughput from 23 to 27 t/ha or by 17.4% if you still consider losses of 1.0% as acceptable.

Since the first threshing machines, engineers have been trying to come to a design which minimises losses. These efforts have not come to an end yet, partly depending on the fact that the combine is used for more and more kinds of crops and the design should be optimal for the new crops as well, without being disadvantageous for the standard crops.

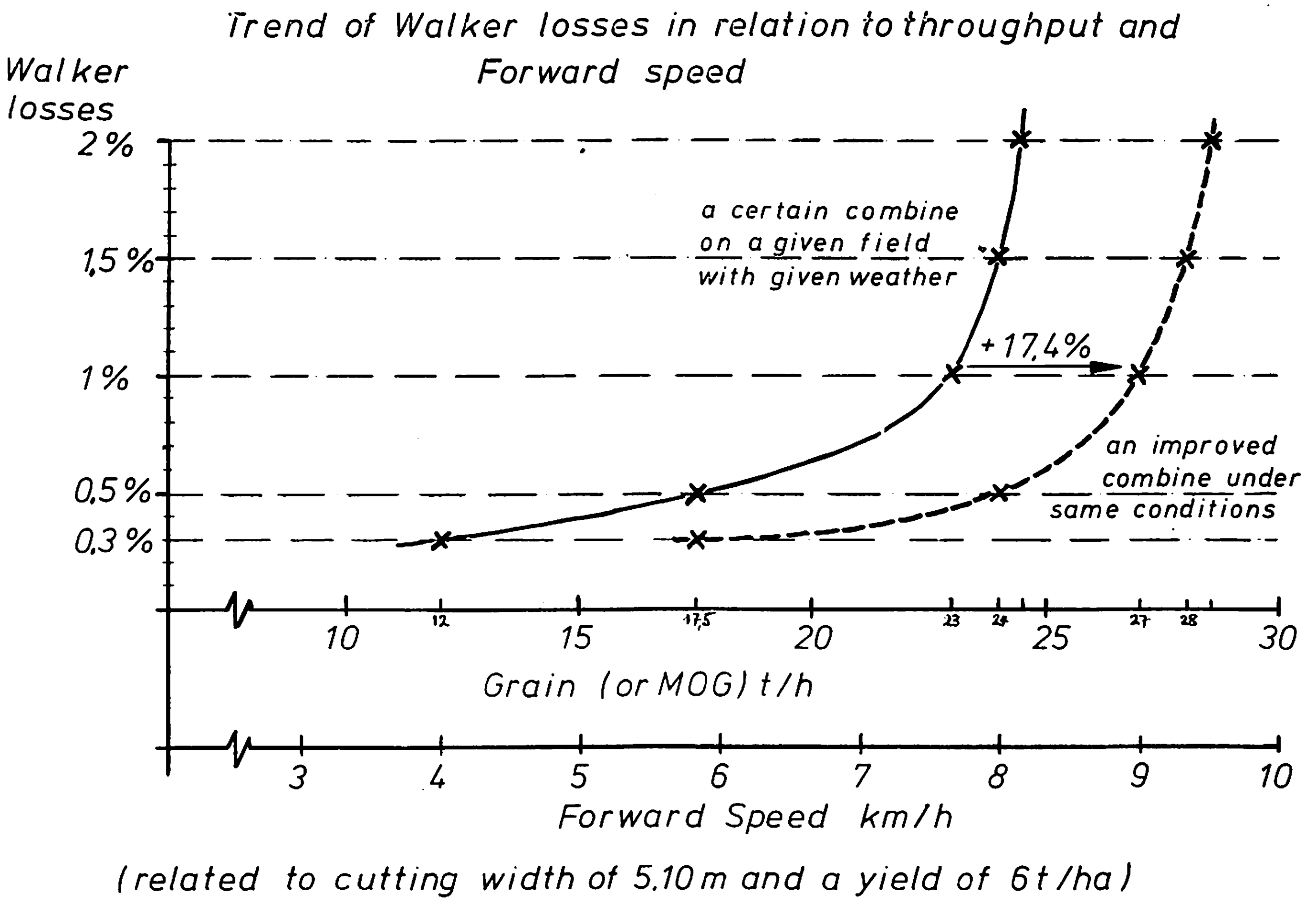
A great number of different influences are playing an important and varying role, according to the field conditions. The difficulty is to find the best compromise.

The walker area is of obvious significance. Nowadays, there are in existence multiples of single walkers only, of these the width is important, the number of steps, the kind of walker deck, the arrangement of the openings, the inclination to the rear, the stroke, the frequency of strokes per minute and the amount of little, but still important things which we call in German "know how"!

Our so called intensive separation system is known as particularly successful. By systematic measurements we know that the separation on the walker is not constant from the front to the rear, but that some areas are more efficient and others less. In Silsoe tests have been made accordingly. By loosening the straw batch from above by a sort of tedder, we gained that the kernels find their way easier through the straw and, therefore, the losses get considerably less. Before this additional accessory came into serial production, we isolated, by a long series of tests, the areas of the most significant efficiency, because it is important to know what distances the tedder crankshafts must have from each other and from other parts of the machine.

**Sieve-pan losses**

Under normal conditions the sievepan losses are minimal. They are about 0.1 to 0.2%. The essential figures are throw and frequency, the slope, the adjustable wind volume and the wind distribution and, of course, the kind of openings of the sieves. The losses increase when working on the slope and under other unfavourable conditions, because the mixture of kernels and chaff is distributed unevenly on



the sieves, and at the same time the wind divides disproportionally too. By guide-plates, which have again a frictional resistance and therefore hold back the material flow and by other precautions, we are improving the distribution on the sieves, particularly when on slopes.

The design which is the most perfect in this relation, is the hill side combine, in which the entire machine stands horizontally by hydraulic means. The additional, technical expenditure is considerable. It is a rule of thumb that a hill side combine costs nearly twice as much as a normal machine. The fact is that the sales are very low, even in Italy only 200 machines/year, which is 70% of the total market. This indicates that the customers consider this investment only economical under extreme conditions. According to the increase of costs the situation can change, of course. Another rare case in which sievepan losses occur, is the harvest in countries with very dry weather and at the same time with dry straw. In the cylinder the straw is crushed and the sievepan has to handle a lot more short straw. This can lead to choking of the sieve and to higher losses. To help us, low cylinder speed, adjustment of the concave and other precautions. Here as well as with the walker, a grain loss monitor can be very useful, as is seen in the next paragraph.

## The types of crop losses caused by the use of combine harvesters

Many of the possibilities given by the design, lead in practice to a reduction of losses only if used well. The following reasons are responsible, but this does not apply in all cases.

### Losses by weariness of the driver

Though today's comfort has been developed mainly with regard to the benefit of the operator, it is at the same time a means for minimising losses or for increasing throughput. In agricultural engineering, of course, comfort is not something new. The horse-pulled mowing machine was a big increase of comfort compared to mowing by scythe, despite the uncomfortable steel seat. In the meantime best cushioned seats with shock absorbers are in general use.

Here we are dealing with the whole environment of the operator, the interdependance between man and machine, called ergonomy.

This includes not only the position of pedals and levers at a convenient place, but to decrease their numbers and the necessary forces too, and to reduce the frequency of handling them. Typical examples are our Retromat, and also the hydrostatic drive which has been known for some time. These devices help indirectly to minimise losses because the driver becomes free for supervision and does not get tired by frequent repetition of routine manipulation. In a similar way may be looked at the already mentioned automatic height control of the cutterbar.

In the same sense we may look at the automatic steering devices that we — up to now — offer only for the maize forage harvester and for picking heads for the combine harvester. By these means the driver is relieved to a degree unknown up to the present.

An additional advantage with regard to minimising losses is the fact that the middle of the rows is met exactly even in fields with much weed or gaps and even with laid crops and at night. The machine goes away from the middle of the rows only for some centimetres and is much more accurate than is possible for a human being, even for a short period.

An important means to avoid early weariness of the driver is the cabin, protecting him from heat and cold, from rain, dust and noise. There is, no doubt, a trend towards air cooled cabins although up to now there are few air condition sets in the price lists of the manufacturers of agricultural machinery in Europe. In the USA 100% of the big combines are sold with cabins and 75% with air conditioning. In UK, on Claas Dominator combines, cabins with coolers are standard equipment.

### Losses by unobserved malfunction

With introduction of the cabin the various monitors gain essential importance. But without cabins as well, they are useful with regard to minimising losses. There are loss monitors in their proper sense and additionally monitors for hand brake, temperature of oil and water, the electric generator, the air filter and the rev/min of several shafts, as the elevator shaft, the shaft of the return auger, of the grain elevator, of the walkers and of the straw chopper.

The grain loss monitor shows if behind walker and sievepan more kernels are falling to the ground than are considered reasonable. Before the grain loss monitor was invented, the operator had to stop the combine, to climb down, to clear off the straw and to estimate whether or not he agreed with the level of losses he found. This has to be done today too, but only once for calibration. Changing yields — not obvious to the eye — can be recognised by the monitor. There is no reason any longer to drive too fast and have too high losses, nor to drive too slow and have too low output.

Monitors for technical supervision of the combine have an effect of loss minimising too, because they cut down interruption time and extend the available time with favourable weather. As this feature becomes more available, the more cabins will be used.

### Losses by non-optimum setting

Up to now, we have looked at a great number of constructional steps determined for minimising losses. Every possibility to adjust a machine is also making possible maladjustment. Though rough faults can be recognised by monitors, it would be much better if the optimal setting were done automatically.

In this regard, certain trends can be noticed, if the solutions — known from patent claims — work out to be economical.

It is intended to adjust the forward speed automatically, according to instantaneous throughput, ie to the local yield. Another idea is to alter also the cylinder speed as a function of the same factors. This cannot be considered as too utopian if you remember that our Claas-Drier-Apollo controls automatically the input of green material as well as the oil consumption according to the instantaneous exhaust temperature.

There is still another idea talked about for many years: It would be desirable to adjust the rev/min of the fan and the openings of the sieves by remote control from the driver's seat. To do this even automatically does not look reasonable, because the cleanliness of the grain has to be looked at too.

These two examples may be enough to illustrate the relationship between automation and loss minimisation. Coming to the end. I have to remind you that with all these devices, the input has to stay smaller than the output. This means, that the last aim is not minimising losses, but minimising the total costs of harvesting, the losses being only a part of them.

The result may be either high throughput and low costs, or low losses. In this regard, the trend towards minimising losses finds its natural limit.

# The minimisation of crop losses associated with sugar beet harvesting

## N B Davis NDA CDA presented by H T Hearn

### Introduction

IN order to minimise losses associated with sugar beet harvesting, it is necessary to discuss the subject in a much wider context than the root losses which occur during the specific act of machine harvesting, important as they may be. The influence of previous cultural practices may be considerable, and may present the harvester operator with conditions largely beyond his immediate control. Even when the crop has been grown correctly and harvested with minimum root loss, the other quality aspects of the work may have a considerable effect on sugar losses which occur during the period between harvesting and delivery of the beet to the sugar factory. The proportion of the total sugar in the root which can be converted to saleable white sugar is also largely determined by the condition of the beet presented to the factory.

### The influence of previous cultural practices on harvesting efficiency

Ever since the days when mechanical harvesting first became a practical proposition in the 1940's, it has been recognised that a properly planned and a well grown crop is essential for sugar beet harvesters to realise their full potential in both output and quality of work. It is even more essential today with the use of multi-row harvesting systems and with mechanisation virtually eliminating the use of hand labour in the spring.

Probably, the factors which aid efficient sugar beet harvesting more than any other are 'levelness' of the field surface and 'evenness' of the crop grown. Assuming that the fields selected are basically suitable then both factors can be influenced by nearly every operation in the sugar beet growing calendar.

The Autumn cultivations of the previous crop stubbles carried out primarily as part of the weed control programme, also afford the opportunity to level any furrows or ridges from previous operations. The increasing practice of applying fertiliser, except Nitrogen, in the autumn before ploughing instead of in the spring, reduces the traffic on the ploughed surface and the tendency to cause wheel ruts. Where belt-type lifting mechanisms are used one must ensure that any deficiency likely to affect the health of the leaves must be corrected.

The primary winter cultivation of ploughing has the most effect in producing a level field and reversible ploughs, although not essential, are the best implements to use for this purpose. It often takes years to obtain the desired degree of levelness in a field and care should be taken not to nullify previous efforts to this and by careless operations during the remainder of the farm rotation period.

Having achieved the basic levelness from the primary operations, the all important spring operations of seedbed preparation and drilling then have to be considered.

First, one must ensure that the correct row width has been chosen to cater for factors such as tyre sizes of the drilling, spraying and hoeing tractors, the degree of row width adjustment on the drill and hoe framework, the amount of adjustment of the tractor track width, and the number of drill units to be operated. The last mentioned factor is of course inter-related with the type of harvester to be operated. Although a good drill-man should be able to make accurate join-rows, it is obviously preferable that a multi-row harvester works on a crop drilled with a matching number of drill units. For example, if a 3-row harvester is to be used a 6, 9, 12, 15 or 18-row drill could be used without the harvester being forced to work across join-rows. Accurate join-rows are of particular importance when single-row harvesters not using in line toppers are operated.

Some debate is taking place at the moment about whether it is more desirable in the longer term to change to drilling in multiples of 6 rows, rather than the present predominance of multiples of 5-rows. The supporters of 6-row multiples argue that a 12 or 18-row drill will accommodate 1, 2, 3 and 6-row harvesters bearing in mind that most of the 5-row harvesters in this country are adaptions from 6-row machines.

Those in favour of 5-row multiples argue that 500 mm (20 in) row widths make it difficult to arrange a balanced drill outfit on the proposed standard tractor track widths without the use of special wheel spacers, and that there is an increasing tendency to 3-row harvesting systems which a 15-row drill would accommodate. Therefore it would appear that drilling in multiples of 6-rows gives more flexibility for catering for a larger number of harvesting systems provided the other disadvantages could be overcome. When drilling the field 'headlands' a sufficiently wide area should be sown around the outsides of the field to ensure adequate turning space for the harvesting system to be used.

Good weed control is essential for any successful system of mechanised beet growing, not only to improve crop yield but also to facilitate easier harvesting. Weed infested crops always take longer to harvest and invariably the harvested beet contains trash and a higher dirt tare because the cleaning mechanisms tend to get blocked with weed debris in difficult soil conditions. Nowadays, weed control is usually obtained with herbicide programmes — pre-sowing incorporation treatments for grass weeds, residual herbicide application for broad leaved weed control at drilling time or immediately after, and post-emergence applications for later germinating weeds. However, weather conditions often dictate whether a particular chemical treatment will be completely successful, so a harvesting system must be capable of dealing with a reasonable amount of weed in a sugar beet crop.

Like weed control, a good plant establishment is essential for good yields and good harvesting. Gaps in a crop tend to produce irregular shaped roots and gaps become full of weeds because the crop competition has been removed. Although the regularly spaced plants from hand singled crops have now been largely replaced by the more irregular plant stands obtained from the drilling-to-stand techniques employed by most growers, harvesters will generally top and lift more efficiently on a crop regular in root size and distribution.

When planting-to-stand the grower has to remember that the average field emergence of sugar beet seed is about 60% and to obtain a target of 75 000 established plants per hectare he will probably be required to choose a seed spacing in the row of about 150—170 mm (6—7 in). Consequently, harvesters have to be capable of dealing with plants of that minimum spacing or perhaps slightly less owing to practical field variations.

With the establishment of a well grown regular crop a good basis will have been laid for efficient harvesting. Even at this stage, however, control of pests and diseases must take place throughout

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the late Spring and Summer and any disease or pest which is allowed to ravage the crop may make it difficult for belt-type harvesters to operate.

**The progress of mechanisation in sugar beet 1960 to 1975**
**Acreage shown as a percentage of national acreage**

| Year | Mech harv-ested | Preci sion drilled | Herbi-cide usage | Pre-emer-gence herbi-cides | Pre-drilling herbi-cides | Post-emer-gence herbi-cides | Planted to stand |
|---|---|---|---|---|---|---|---|
| 1960 | 55 | 24 | 0 | 0 | – | – | – |
| 1961 | 75 | 35 | 5 | 5 | – | – | – |
| 1962 | 84 | 46 | 9 | 9 | – | – | – |
| 1963 | 88 | 58 | 13 | 13 | – | – | – |
| 1964 | 92 | 65 | 18 | 17 | 1 | – | – |
| 1965 | 95 | 74 | 35 | 32 | 4 | – | – |
| 1966 | 94 | 86 | 47 | 44 | 6 | 0 | 1 |
| 1967 | 95 | 90 | 64 | 60 | 7 | 1 | 4 |
| 1968 | 97 | 95 | 71 | 66 | 8 | 2 | 12 |
| 1969 | 100 | 100 | 77 | 72 | 9 | 5 | 19 |
| 1970 | 100 | 100 | 85 | 80 | 11 | 6 | 30 |
| 1971 | 100 | 100 | 90 | 80 | 15 | 9 | 32 |
| 1972 | 100 | 100 | 91 | 78 | 16 | 14 | 35 |
| 1973 | 100 | 100 | 95 | 80 | 21 | 40 | 39 |
| 1974 | 100 | 100 | 96 | 76 | 25 | 60 | 52 |
| 1975 | 100 | 100 | 98 | 71 | 26 | 72 | 65 |

## Reducing root losses during harvesting

In the days when farm workers were quite numerous, high root losses on the field were gleaned and the 'defects' of earlier mechanical harvesting systems were then quite easily rectified. Towards the end of the 1960's it was becoming increasingly clear that workers were no longer available for such tasks and as a consequence the need for more efficient mechanical harvesting became obvious. In many cases growers did not always seem to be aware of the amount of loss taking place and with this in mind British Sugar started a series of root loss investigations in 1971 to bring the matter to the attention of those concerned.

On the agricultural staff at each sugar factory there is now a factory agricultural development officer who has received specialist training in all aspects of growing a sugar beet crop and with special emphasis on mechanical matters. During the 1971/72 harvesting season, nine of these officers and their fieldman colleagues carried out a survey of roots found in the wake of harvesters. The intention was to ascertain the extent of the losses and, if possible, to identify the reason for them. For the sake of convenience losses were classified according to whether they were gleaned from the surface (surface losses) or whether they were recovered after a length of row had been dug (dug losses) with the aid of lifters, in the form of modified sub-soilers. The sample area was 30.6 m (100 feet) long and five rows wide for surface losses and a similar length of single row was examined for each dug loss. Visits were made throughout the season and on each occasion five surface and five dug losses were collected, rough cleaned and weighed in the field.

The visits embraced a wide range of soil conditions, harvester types and operator skills and it proved impossible to ascribe the cause of a loss to any one factor. Obviously the setting and operation of a machine has always been a compromise between trying to harvest the maximum quantity of saleable crop while avoiding lifting an excessive amount of soil. If the lifting devices are set sufficiently deep and the machine driven slowly, every root should be gathered, but there is a serious risk that excessive amounts of soil will be lifted and accompany the beet into the clamp via the direct tipping trailer.

The 1971/72 season produced good harvesting conditions and during the early part of the campaign the soil was dry and hard and the average loss (surface plus dug) from 39 visits was 3.29 tonne/hectare (1.37 ton/acre). As conditions improved the figure fell to 2.23 tonne/hectare (0.93 ton/acre) and rose later to 3.29 tonne/hectare (1.37 ton/acre). The weighted average for the whole season was 2.81 tonne/hectare (1.17 ton/acre) with dug losses accounting for 63% of the total. However, averages mask the more striking figures of: 3.86, 7.15, 9.14 and 12.14 tonne/hectare (1.61, 2.98, 3.81 and 5.06 ton/acre), which were the peak figures recorded in different areas of the country. At least two examples supported the contention that the setting of the machine was as important as the type of harvester. In one case surface losses were reduced from: 1.51 to 0.84 tonne/hectare (0.63 to 0.35 ton/acre) by merely reducing the power-take-off speed, in another, total losses were almost halved (7.15 to 3.84 tonne/hectare) (2.98 to 1.60 ton/acre) when the forward speed was reduced from 8 k/h to 4.8 k/h (5 m/h to 3 m/h).

As might be expected, the surface losses consisted mainly of whole roots whereas the dug losses consisted mainly of broken root tails. The importance of the dug losses was emphasised by the fact that in 85 out of the 152 visits, the dug losses exceeded the surface losses and the general conclusion from this first survey in a comparatively easy harvesting season was that beet losses were often considerably higher than expected.

A similar survey was carried out during the 1972/73 campaign and the total losses recovered from fields after harvesting averaged 2.77 tonne/hectare (1.10 ton/acre) of which 34% was collected in the form of surface loss. These figures were very close to those recorded during the previous year with both years being comparatively easy harvesting seasons. Again this second survey did not reveal any single cause as being primarily responsible for loss of roots during harvesting and it was planned to carry out a more detailed study in the following year.

Consequently in 1973/74 factory agricultural development officers visited 243 sugar beet harvesters and recorded surface and dug losses and with a further requirement to identify the sources of the losses and to proportionately allocate them to six out of a list of 33 reasons! In this survey 32% of the fields visited had a total loss of exceeding 3 tonne/hectare (1.25 ton/acre) and in fact averaged 5.90 tonne/hectare (2.40 ton/acre) of which 34% was gathered from the field surface. In one instance no less than seven tons per acre was found in the ground.

The fact that the survey is based on approximately a one per cent sample necessitates treating the results with due reserve but the figures shown in the following table indicate that the implications cannot be ignored.

*Table I Total losses 1971–1973*

| | | 1971 | 1972 | 1973 |
|---|---|---|---|---|
| Total losses – | tonne/ha | 2.90 | 2.70 | 3.10 |
| | ton/acre | 1.17 | 1.10 | 1.26 |
| % on surface | | 37 | 34 | 40 |
| National yield – | | | | |
| | tonne/ha | 42.80 | 34.20 | 38.70 |
| | ton/acre | 17.33 | 13.86 | 15.68 |
| Losses as per cent of national yield | | 6.75 | 7.94 | 8.04 |

Practical considerations prevented any conscious pre-selection of machines or fields and in practice it was a case of visiting those fields in which harvesting was taking place on the day chosen for the work.

The more detailed studies carried out in 1973/74 enabled the following comments to be made.

With regard to the time of harvesting, losses increased from 2.5 tonne/hectare (1.02 ton/acre) in October to 4.25 (1.71) in January and most of this increase occurred amongst the harvesters using wheel type lifters as can be seen in the following table.

*Table II Type of lifter – total losses tonne per hectare*

| Lifter type | Wheel | | Share | | Belt | | All types | |
|---|---|---|---|---|---|---|---|---|
| | No.* | t/ha | No. | t/ha | No. | t/ha | No. | t/ha |
| October | 48 | 2.56 | 6 | 2.66 | 4 | 2.68 | 58 | 2.56 |
| November | 43 | 3.26 | 12 | 3.01 | 17 | 1.88 | 72 | 2.96 |
| December | 63 | 3.69 | 14 | 2.39 | 9 | 2.84 | 86 | 3.38 |
| January | 22 | 4.72 | 2 | 2.82 | 2 | 2.19 | 26 | 4.39 |
| Seasonal average | 176 | 3.41 | 34 | 2.68 | 82 | 2.39 | | |

*No. of machines sampled.

*Table III Effect of method of crop production*

| | No sampled | Average losses tonne/hectare | | | Surface loss % of total |
|---|---|---|---|---|---|
| | | Surface | Dug | Total | |
| Hand singled | 121 | 1.08 | 1.71 | 2.79 | 39 |
| Drilled to stand with hand trimming | 53 | 1.45 | 1.68 | 3.13 | 46 |
| Drilled to stand without handwork | 68 | 1.48 | 2.53 | 4.01 | 37 |

There was a slight indication that losses were higher on narrower rows but this may be related to the fact there is a greater 'yardage' of rows rather than the inability of the harvesters to cope with these crops.

With regard to soil type, there were indications that the losses

*Table IV Type and condition of soil — total losses tonne per hectare*

| | Very dry | | Dry | | Moist | | Wet | | Very wet | | All conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No.* | t/ha | No. | t/ha | No. | t/ha | No. | t/ha | No. | t/ha | No. | t/ha |
| Sands | 4 | 4.27 | 7 | 1.61 | 20 | 3.06 | 2 | 1.86 | 1 | 1.91 | 34 | 2.78 |
| Loams | 1 | 12.07 | 9 | 3.74 | 94 | 2.84 | 32 | 2.21 | 2 | 2.61 | 138 | 2.76 |
| Clays | 1 | 8.16 | 3 | 1.64 | 26 | 4.61 | 16 | 3.77 | 7 | 8.98 | 53 | 4.85 |
| Others | | | | | 5 | 2.15 | 11 | 2.61 | 2 | 2.84 | 18 | 2.51 |
| All soils | 6 | 6.20 | 19 | 3.74 | 145 | 3.59 | 61 | 2.68 | 12 | 6.30 | | |

*Number of machines sampled.

increased as the soil type became heavier although this is influenced by the dryness of the soil. It was not possible to show the effects of soil types on different harvesters owing to the smallness of the sample but Table IV does show the penalties of harvesting in very dry or very wet conditions.

When the type of harvester was examined, it was found that the highest losses were recorded against single stage harvesters, but speed of travel did not appear to influence the total amount of beet lost. However, excessive forward speed would obviously affect the performance of a harvester.

When the causes of losses were examined, it was seen that 'lifters too shallow' and 'off-row steering' were blamed for over 25 per cent of the national loss of 3.1 tonne per hectare (1.26 ton per acre) in 1973/74 and for over 32 per cent of bad cases with an average loss 5.9 tonne per hectare (2.40 ton per acre).

The frequency with which each cause occurred is shown below as a percentage of the total number of causes reported and in the order of ranking. The contribution of each cause made to the national total loss is also shown with its decile ranking.

*Table V Causes of losses*

| | All machines | | | |
|---|---|---|---|---|
| | Frequency of occurrence | | % of national loss | |
| Causes of loss | % | Rank | % | Rank |
| 1 feeler wheel teeth worn | 4.1 | 9 | | |
| 4 topper knife blunt | 3.8 | 10 | | |
| 5 topper knife setting | 4.2 | 8 | 3.6 | 10 |
| 9 flipper too low | 8.8 | 3 | 7.0 | 6 |
| 11 lifters too shallow | 8.5 | 4 | 13.3 | 1 |
| 13 lifters too wide | | | 7.6 | 4 |
| 15 loss through wheels | 6.9 | 5 | 4.1 | 9 |
| 17 chain worn | 9.5 | 2 | 6.2 | 7 |
| 20 off-row steering | 9.9 | 1 | 12.8 | 2 |
| 21 off-row steering sloping land | | | | |
| 22 travelling too fast | | | | |
| 23 losses during discharge | 5.8 | 8 | 4.2 | 8 |
| 29 bolters | 6.9 | 5 | 8.2 | 3 |
| 30 crop irregularity | 5.9 | 7 | 7.3 | 5 |
| No of machines in sample | 243 | — | — | — |
| No of causes listed in sample | 875 | — | — | — |
| National average loss tpa | — | — | 1.26 | — |

The two principal causes of loss, found in the survey, point to certain design changes. Improvements in the lifting and cleaning mechanisms to minimise the amount of soil would allow the former to be set deeper.

The universal use of better depth control attachments would also help in this respect. The more widespread adoption of 'row seekers' allowing the lifter units to move laterally would probably reduce the 'off the row steering' losses because quite often the operator does not have a good view of the lifter units. It is interesting to note that many of the continental machines fit these more sophisticated items of equipment as standard and obtain the desired results.

Another obvious adjustment which is not always made is to ensure that the outside wheels of the tractor and/or harvester run in the furrow of a lifted row of beet to give stability to the outfit. The reason often given for not doing this is the tediousness of the adjustment, so the moral would seem to be that any adjustment should be capable of being carried out easily and quickly and preferably by one man.

These surveys tend to show that Mr 'Average Grower' is leaving more than 2.5 tonne/hectare (1 ton/acre) on every acre. This is equivalent on 500 mm (20 in) rows to 6.6 lb/chain of which 2.4 lb is on the field surface. Thus an average sized root of 0.6 kg (1.5 lb)/chain (20 m) on the field surface indicates a probable loss of 2 tonne/hectare (¾ ton/acre). Our aim should be to reduce this by at least half.

Obviously the national average loss is being hoisted by one grower in three who leaves 5 tonne/hectare (two tons/acre) and the greatest benefit will come from reducing this level of loss.

Some of the more common practical maintenance points which often get overlooked concern the topping units and the flails used to remove debris from around the topped roots. The traditional type of knife topping unit should always be checked for height adjustment and the feeler wheel kept adjusted with its teeth sharpened at regular intervals.

Blunt knives are often a source of poor work because they are not sharpened or replaced as necessary. A blunt topping knife tends to push roots over as well as doing an inefficient topping operation. The loosened roots then get knocked out of the row by the flail and this constitutes a serious surface loss. Probably there is need for research into a knife which will remain sharp for much longer periods.

The roots knocked out of the row can be quite easily gathered by the fitting of single rakes to a harvester as has been demonstrated by British Sugar's Field Station but the idea has never been taken up by manufacturers.

High plant populations usually result in smaller roots and harvesting of such crops can be a problem in dry weather conditions. For such conditions the need for elevator chains with a narrower pitch is desirable but growers are often reluctant to use such chains because the wider pitch chains are usually required for the later wetter conditions in early Winter. Consequently it would be of considerable help if a variable pitch elevator chain could be developed which could be used on both harvesters and cleaner-loaders.

The harvesting of small beet also requires 'spiders' to be fitted to oppel wheels early in the season and anything which can be done to simplify the fitting and removal of these would encourage more growers to use them.

Excessive amounts of weed growth or bolters may require special treatment in order to aid harvesting efficiency and 'slashers' preceeding the topping unit are useful pieces of equipment in such circumstances.

Where the inside tractor wheels run in the growing crop, some of our factory agricultural officers have found it a distinct advantage to fit twin rear narrow row crop wheels in place of the standard wider wheel. This not only gives greater stability and better traction but also eliminates the disturbance of roots by wide tractor tyres before harvesting.

Another cause of loss is often the simple operation of elevating beet from harvesters into trailers. Usually all that is required is a little care and common sense but sometimes trailers are used which are not really suitable. Provided this final stage of harvesting can be successfully accomplished the grower is then left with the task of storing and delivering his beet to the factory with minimum loss.

## Reducing sugar losses during 'On Farm' storage

The pattern of sugar beet harvesting in the United Kingdom is such that the beet grower harvests sufficient of his crop during the early part of the 'campaign' only to keep pace with his delivery programme to ensure that high stocks of harvested beet are not accumulated when ambient temperatures are relatively high. But from early November onwards the rate of harvesting is increased with the object of completing harvest by Christmas (earlier on heavier soils) which should ensure that all beet are out of the ground and safely clamped before the onset of any severe weather which does not normally occur in this country until the turn of the year. However, the processing period at the factory will probably continue until about mid-January in a year of average yields but in a high yielding season the factory 'campaign' may not end until February. Consequently most growers will store a proportion of their crops on their farms for some weeks before their deliveries are completed. Although late delivery bonuses are paid to growers to compensate for the usually slight sugar loss which occurs during the period of storage, it is obviously in the interest of the industry generally that this loss is minimised, and this is largely influenced by the condition of the beet entering the storage clamp and the clamp environment during storage.

The question is often asked as to what type of clamp should be built to minimise losses and to ensure that the beet are in a good processing condition when they finally arrive at the factory. No single type of clamp is correct for all circumstances but certain general principles of good storage have been established by numerous trials and respiration studies carried out by British Sugar's staff over many years.

Severe sugar loss is incurred if beet is allowed to freeze and then thaw. Under such conditions the beet cells containing sugar burst and allow micro-organisms present in the beet to destroy the sugar and convert it to invert sugar and gums. Invert sugar causes difficulty in the sugar factory by making the juice more coloured and by making acids. This results in reduced extraction which is the amount of sugar in the beet which can be converted into crystalline sugar. The gums reduce the rate at which the juice can be filtered and as a consequence reduces the rate at which the beet can be sliced. This in turn affects the rate at which deliveries of sound beet can be accepted at the factory.

It has been found that beet clamped in early December and which were mildly frosted have lost 15–20% of their sugar by early January and all sugar is lost from severely frost-damaged beet. Therefore, it is obvious from both the grower's and the factory's viewpoint that frost damage to stored beet must be prevented and this can only be done by covering clamps when severe weather threatens.

Covering clamps can also bring its problems because beet respire and one of the main objectives of good clamping is to keep respiration to a minimum. During respiration sugar is consumed and eventually produces carbon dioxide. With normal respiration the rate of sugar destruction is very slow compared to the rate at which micro-organisms attack sugar in frost damaged beet. However, if the beets become warm, respiration increases and because respiration itself produces heat, the reaction is self-perpetuating. Therefore, covering must be carried out with care if overheating is to be avoided.

Another point to be borne in mind is that roots respire very rapidly for the first four or five days after harvesting but after this initial period the rate of respiration usually falls to a steady level provided the correct clamping conditions prevail. Thus it is bad practice to apply covering materials to beet immediately after they have been clamped unless very severe frosts are imminent.

During mild weather periods it is preferable not to cover clamps but covering material should be available on the clamp site so that it can be quickly applied when frost is forecast. Straw is still the most suitable covering material available to most growers but attempts have been made to popularise other materials such as polythene sheets. So far the alternative methods have not been successful on a large scale because polythene sheets, for instance, can cause ventilation and anchorage problems.

There is obviously a need for a relatively cheap, quick and practical method of clamp covering which can be easily removed when required.

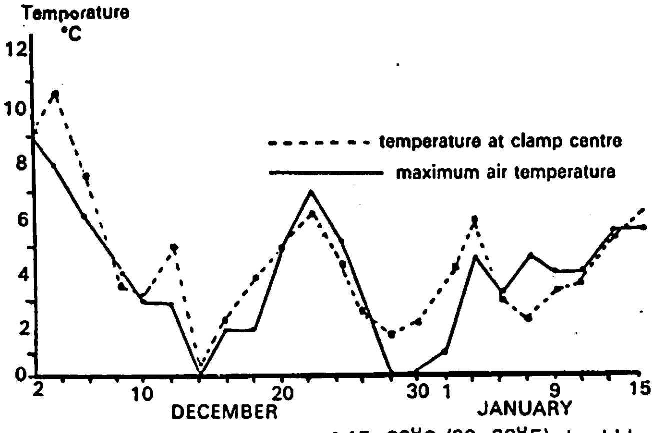
When ambient temperatures are above freezing point the main need to keep sugar loss in clamps to a minimum, is to dissipate the heat caused by respiration or other factors. Overheating can be the cause of serious trouble in clamping and in this respect it has been found that clamps built with, say, two courses of straw bales as retaining walls will overheat. Temperatures of over 15°C (60°F) (which is the maximum clamp temperature commensurate with an acceptable rate of sugar loss) have been found in such clamps because the bales prevented cooling by natural ventilation. Consequently if bales are used to help in forming a tidy clamp they should be removed as quickly as possible to aid the dissipation of heat caused by the initial high rate of respiration of freshly harvested beet. For the same reason care should be exercised when clamping against walls, stacks or in any conditions where ventilation is impeded.

Ventilation is important in preventing overheating and there are a number of things to consider in trying to provide adequate clamp ventilation. When constructing a clamp care should be taken not to break roots because small pieces of smashed roots respire quicker than whole roots and will also tend to block the air channels in the clamp. This can happen when clamps are made with fore-end loaders. Similarly, green material in the form of leaves and stalks also respire much more rapidly than roots and can prevent the free flow of air.

Too much dirt in clamps is also very bad and is probably the biggest single cause of overheating. Large square clamps, although making the best use of storage space and exposing least surface to the weather, provide less ventilation than apex-type clamps. For this reason it is usually recommended that apex-type clamps are built during the early part of the campaign when air temperatures are relatively high, and the large square clamps are constructed later in the season when temperatures are lower and storage space is at a premium. Whatever the type of clamp it is important that the shape should be regular. Any hollows will provide sites into which water will drain as well as creating admirable frost pockets. The more widespread use of high-tipping trailers now enables large clamps to be built to a regular shape with a minimum of 'tidying up'.

When high-output harvesting systems were first introduced, overheating was the cause of a very considerable loss of sugar in some large clamps, particularly on farms where beet were being harvested with multi-row machines producing sufficient beet each day to complete a large clamp. These beet had a high dirt tare together with a poor standard of topping and they were steaming after a relatively short period in clamp. These extreme cases resulted in a considerable loss of beet and the lesson should be borne in mind as we progress towards the greater use of high-output harvesters. With such machines it may be preferable to build several clamps simultaneously to make it easier for the initial rapid respiration to subside before each clamp is completed.

Experimental experience has shown that a good guide to clamp behaviour is by simply monitoring clamp temperatures with thermometers placed in various parts of the clamp, particularly those places where ventilation is likely to be worst. This can be done quite simply by inserting suitable lengths of 120–130 mm bore rigid, pvc or metal piping into clamps during construction. Thermometers attached to a length of wire can then be inserted in the piping to give a measure of the temperature inside the clamp. The accompanying graph shows temperatures which were recorded at the centre in a well kept clamp of beet during the 1968/9 campaign. It will be seen that the clamp had not overheated, the clamp temperature having never been greatly in excess of the maximum air temperature.




Internal clamp temperatures of 15–20°C (60–68°F) should be regarded as high enough to remove any clamp covering (should it be applied) until the internal temperatures fall below 10°C (50°F). At temperatures above 20°C (68°F) the clamp should be opened-up.

Generally internal temperatures in the range 5–15°C (40–50°F) would be acceptable and when they fall below 5°C (40°F) it might indicate that beet on the outside of the clamp are in danger from frost damage.

Only healthy well topped beet should be clamped and in no circumstances should frozen beet be put in a clamp. This can arise where topped rows of beet are left exposed to overnight frost and the amount of damage is not fully realised. Obviously it is best if all topped rows are lifted at the end of each day's working.

## Loading and delivery to the factory

Although losses during the final stages of loading and delivery to the factory are unlikely to be high, careless use of loading machinery on poorly sited clamps can occasionally cause significant root loss.

A concrete base of adequate dimensions strategically sited next to a good access road yet not too far from the beet field is the basic requirement for good storage and loading. Whilst the use of concrete pads is increasing to an encouraging degree many growers are still forced to clamp at least a proportion of their crop on a soft loading base — usually a corn stubble or a grass field. Provided such a site is chosen carefully and care is taken during clamp making and loading, it can be quite adequate.

Obviously the careless use of a fore-end loader on a soil base can smash a lot of roots and cause excessive amounts of soil from the

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# The design and operation of pea viners and bean pickers as they affect crop loss

A T Bain

THIS paper is intended to cover the causes of waste and hence the operation of modern pea and dwarf green bean harvesting machines, but I should like to concentrate first on pea harvesters.

Although the first static viner was invented in 1885 by Madame Faure in France the use of in-field mobile machines has only occurred on a large scale in the UK in the last 10 to 15 years. It is interesting to note that the basic principle has never changed but only been refined. The introduction of mobile viners did represent a major breakthrough in operating technique of great benefit to all users. In retrospect it is perhaps unfortunate that this major advance was so readily seen and so quickly acted on as it appears to have resulted in a lot of original faults in operation being continued through to the present day.

We have been assessing the performance of existing and new machines continuously for the last ten seasons, and have built up a fairly large history of performance data. Obviously we have refined our techniques over the years as we have gained experience. I must admit that looking back over some of our early results I am not too impressed with our early methods and their presentations, and would not be too happy in quoting them without reservation. I do believe that the results we have obtained in the last few years are as accurate as possible.

In order to determine the wastage which occurs in a pea harvesting operation one must first identify the areas in which losses can and do occur. These are:

**(a) Cutters**

Many of the losses attributed to the pick-up area of a mobile in fact are not its fault. Ideally the cutter reel should lift the crop and present it to the knife ready for cutting. To do this it is essential that the speed of the reel is adjusted to suit the conditions. When a crop is laying away from the cutter the reel must rotate faster relative to ground speed than when the crop is laying towards the cutter. Yet it is a common sight to see cutters operating up and down the crop with no change in relative speed. The result is a combing of the vine by the tines and an arising of loose pods. This condition may not be obvious when looking at the windrowed crop but as the vine is teased up by the mobile pick-up loose pods fall back onto the ground. We have recorded extreme cases of a 10% loss at this point which are directly the result of poor cutter operation.

It is interesting to note that the latest advance in pea harvesting, the so called pea pod picker, probably more accurately called the vine reducing mobile, makes use of this principle.

Another area in which the cutter can have an adverse effect on yields is in the viner threshing drum. The more tangled the vine entering the drum, the more difficult it is to thrash and the greater the yield loss in the silage.

A side discharge cutter acts like a weavers spinning wheel producing a rope of vine difficult for the drum to handle. Centre discharge cutters are better but not perfect in this respect. The only comparative results we have were taken when testing a rather novel and unsuccessful harvester and therefore cannot be considered accurate but they did indicate higher yields and/or faster speeds from windrows formed by centre discharge cutters.

**(b) Pick-up and drum feed**

As stated previously most of the losses in this area are really attributable to the cutter. Except on the lightest crops all modern pick-ups are capable of handling with little loss all of the crop available. Unfortunately they often have to be operated at less than optimum to compensate for poor cutter performance.

**(c) Threshing drum**

Although the basic principle has not altered over the years, we have in the last 5 or 6 years seen fairly drastic changes in design, off-set beaters, teasing units on the beater shaft, three and five beater shaft configuration have all contributed more to through-put than to yield, although to be fair some of the later designs have increased yield by a reduction in damage levels.

Once a pea has been removed from the pod it must escape from the drum as quickly as possible to avoid further damage. To achieve this without also removing excessive whole pods the screen mesh must maintain a constant size both because of its inherent strength and by staying clean. At the same time it must not present sharp edges to the pea. The most successful design uses rigid plastic coated wire screens, formed to the circumference of the drum so that an external rotating brush can be used to clean it.

It is amazing how many machines still use hexagon drums with woven rope screens and no cleaning when one considers how easily even old machines can be converted to the more modern system.

**(d) Pod and stick eliminator**

The problem here appears to be not so much how they work, as they are usually very efficient, but more where they discharge pods for recovery. On some machines this is on to the elevator section of the pick-up rather than direct into the drum. Apart from the risk of lost pods during elevation to the drum while working, nearly all the pods discharged here are lost when no

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ground surface to be loaded with roots and in such situations it may be preferable for grab loaders to be used which produce less wheel traffic on the site.

Cleaner-loaders are a useful 'filter' for giving the beet a final clean before delivery to factory. However, unless the pitch of the chains is similar to that of the harvester, small roots can be lost as can any smashed roots broken by the tractor-loader feeding the cleaner-loader.

Although the root loss caused by beet falling from lorries on route to the factory is not the problem it was some years ago, it can still occur and a correctly loaded lorry will prevent such a loss as well as obviating a hazard to other road users.

## Conclusion

Hopefully this paper has established that minimising crop losses associated with sugar beet harvesting is not solely a function of the design of the harvester and its operation, although there is considerable room for improvement in these spheres of activity. The growing of the crop must be carefully planned and executed and sufficient attention must be paid to the storage and delivery procedures.

vine is being picked up. If you consider the number of occasions when a machine is still running but not picking up a windrow eg turning at the ends of a row or waiting to discharge, the potential losses become worth considering.

**(e) Cleaning systems**

Generally speaking cleaning systems are infinitely adjustable. Where the results of these adjustments are easily identified losses can be kept to a minimum. Aprons and blowers fans the full length of the apron give little problems.

Unfortunately there appears to be a move towards suction fan cleaning often termed in my Company 'bury your dead cleaners'. Anything passing through one of these high speed fans is so chopped as to be unidentifiable so that while it may be producing a clean product it is impossible to tell if it is also removing whole pods, good peas or an excess of splits and skins and therefore hiding a poor performance in other parts of the machine. Because their design always requires a high product density per unit of cleaning area they are much more sensitive to throughput requiring more accurate and frequent adjustment if they are to perform satisfactorily. One machine design has now achieved what I hope is the ultimate in horrors in this system, two suction fans in series both discharging in inaccessible places, so that even the minced discharge is difficult to examine.

However critical we may be about the latest machines we have to admit that they have improved dramatically in the last few years, not only in speed but in increased yields.

During the 1975 season we had the opportunity to re-test some 1968 and 1969 machines alongside a new pre-production machine and therefore obtain a direct comparison. The figures were as follows on a theoretical yield of 2.37 tons/acre.

| | *Old machine* | *New machine* |
|---|---|---|
| Harvesting rate | 0.6 acres/h | 1.29 acres/h |
| Peas left on field | 0.7 tons/acre (29%) | 0.08 tons/acre (3.4%) |
| EVM in tank | 1.7% | 7% |
| Damaged peas | 18% | 11% |
| Total waste peas | 47% | 14.4% |

At first glance it appears that the manufacturers are giving us the best of both worlds, progressively greater outputs and proportionally reduced yield losses. Unfortunately this is no longer true. The last three new machines we have tested have had little change in yield loss although speed has increased from 1.13 acres/h to 2.04 acres/h. At this stage presentation of the figures can become all important and if carefully done, can suggest something very different. Returning to our example, damage and EVM is often quoted together, in this case it has reduced from 19.7% to 18% a 1.7% saving, but this is much more likely to be quoted at a 8.6% reduction in waste. A much more impressive figure. It is at this stage the suction fan comes into its own, turn up the fan, down goes the EVM and damaged pea levels and up goes the apparent yield, of course down comes the actual yield, but how do you measure it.

We normally try to sum the yield loss figures from our test with the yield from the machine to give a theoretical field yield but when some of the loss areas are unmeasurable this is not practical. The only alternative is a statistically reliable hand picked trail requiring 20 to 30 random one square yard areas of the field to be hand picked and podded just before harvesting. Without an army of helpers this is just not possible in the time available.

There is a danger that the difficulties of comparing machine performance against the theoretical yield may force us to adopt instead only comparison trials of machines and lose sight of the real losses still occurring.

Our example showed the newer machine with a yield loss of 14.4%. If as is likely the processor is prepared to pay for up to 8% damaged peas the actual loss to the producer is 6.4% — worth say £125/ton at the factory or a loss of nearly £19/acre. The loss to the processor is likely to be at a similar or higher level as he must either remove the damaged peas at an additional on-cost or accept a down graded pack with a lower retail value.

It is natural when discussing waste to consider first waste of product. I feel we are rapidly reaching the stage where the direct waste of money is becoming more important.

There is a basic and correct rule particularly in the frozen food section of the industry which says, the field must supply the factory needs at all times to produce maximum factory utilisation, because this is the area of greatest capital investment and highest revenue costs. From this rule has grown the mystical 'worst pea season' defined roughly as follows:

1. There will be monsoon rain proceeding and all through the season.
2. Very low yields.
3. Galloping TR's.
4. A shortened season.
5. All field equipment will have poor engineering utilisation.
6. The factory will experience *no* breakdowns.

Some of the above statements are so contradictory as to be virtually impossible. Anyway it was on this basis that acreages/machine were originally allocated giving plenty of sleeve for all the unknowns and unpredictables. Unfortunately every time we introduce a new machine into the system the sleeve grows larger as each member of the chain, manufacturer, user and processor adds his own extra safety margin.

It's probable that most modern machines can be expected to achieve an overall utilisation of 70%, a large proportion do not actually operate at better than 50% and we know of figures as low as 30%. With the latest machinery costing over £50 000 each this is becoming a major cost factor. It is going to become increasingly important that we so organise the harvesting structure that the maximum possible use is made of both labour and machine.

Equally the machinery breakdown utilisation loss grows more significant with each advance. If you were replacing old Scotts or Mather and Platts next year it could be for pea pod pickers and you might well be considering two machines to replace six. Which is all very attractive until you realise that one breeakdown replaces three and the machines are a lot more complex. Some of the manufacturers appear to have a Jeckell and Hyde character over this aspect of their machines. They seem to accept the need for greater reliability and design their machines to suit as far as the major components are concerned. Then you discover for example, levelling valve solenoids not continuously rated which burn out when operating on slopes at or above the maximum levelling capacity, even though anybody on hilly ground inevitably does this. Or hydraulic system with single braid hose when double braid is only marginally more expensive with twice the safety factor, particularly important when you can still buy machines which will roll over when a single hose bursts on a levelling system.

Dwarf green bean harvesters have in the past always been entirely different in design from the pea mobiles, although with the advent of pea pod pickers and multi-row bean harvesters, the similarities have increased to the point where one manufacturer now offers a common machine with change parts for both crops.

There have been some major advances in bean harvester design in the last few years which dramatically increased throughput and usually improved yields with lowered damage levels.

Most of the major yield loss and damage occurs at the picking reel and is therefore the area to concentrate on when discussing these problems. At present there are three different methods of presenting the picking reel tines to the crop, each of which has its own problems in operation.

**(a) Single or twin row harvesters**

In these machines the axis of the picking reel is parallel to the row and angled to the ground so that the reel contacts the tip of the plant at its leading edge and the bottom of the plant at the rear. As the machine moves forward the plant travels between the outside edge of the reel and guide plate. This plate continues up over the reel. The reel is turning so that the tines in contact with the plant are moving upwards.

The reel speed has to be selected to first ensure sufficient tines pass through the plant for efficiency picking and secondly to guarantee that the bean velocity after leaving the reel is high enough to propel the bean up and over the reel to the transport belt. The relationship between the tine and the plant is such that a proportion of the beans are thrown outward against the guide plate from which they bounce back into the reel and are struck again to propel them over the reel to the conveyor. There is a very high likelihood of damage occuring at this point.

Other beans become trapped in the reel between the tines and unless removed on the inward side, fall to the ground and are lost. Removal of these beans requires the fitting of a fixed comb between the tines which in turn produces more damage. It incidentally also limits the possible tine configuration and therefore tends to lower the picking efficiency.

Any beans which are just caught by the top of the tine are not propelled upwards and fall down between the reel and guide plate onto the ground. It is impossible to design the machine to avoid this problem.

The harvester must be guided down the row with considerable accuracy and this is not always possible in very wet conditions. Errors in excess of ±3 in will have a great effect on picking efficiency. On twin row machines a further complication arises in the matching of two rows and it becomes essential to use drills with an even number of rows so that the two reels are not required to operate on rows drilled on different passes.

**(b) Multi-rows with forward driven reels**

The introduction of mutli-row machines was a major breakthrough in the bean harvester design. The axis of the reel is parallel to the ground, and at right angles to the direction of travel. They can operate in any direction although are not at their best running directly across the rows. One advantage is the ability to reduce the headland to the minimum required for turning the drill with a potential yield increase.

On multi-rows using what I have termed forward driven reels, the reel turns so that the bottom tines are travelling in the same direction as the machine. A guide plate extends from in front of the reel, a few inches above the ground and over the top of the reel. As the machine moves forward this plate pushes the plants over so they lay away from the reel, and the tines at the bottom of the reel pick the plant progressively from bottom to top.

Picked beans are propelled forward and up and rely on the guide plate to stear them through 270°, over the reel to the conveyor behind it. As might be expected damage is generally higher than with the previous machines.

It is not as essential to fit combs to this type of reel but some yield loss does occur with beans carried over in the tines. Most of these beans go right round again and although not lost are at risk for increased damage.

Because the plants are laid over they form a carpet on the ground and any beans picked off but not carried over fall on this carpet forward of the tines and are picked up as the machine moves forward. This gives this type of machine a distinct advantage in yield loss terms over the single row type.

**(c) Multi-row with leading belt**

The only major difference between this machine and the simple foward driven reel design is in the provision of a slatted conveyor forward of the reel. This conveyor is the full width of the reel and angled to the ground so that its leading edge is above plant height and its trailing edge 3 or 4 inches above the ground. It is driven so that the underside is moving in the reverse direction, and faster than the forward speed of the machine. This lays the plant towards the machine so that the reel picks from top to bottom of the plant and then as the reel passes over the root from bottom to top. This gives twice the picking chances with a noticeable yield advantage. Beans are thrown forward onto the belt for cleaning.

Because the beans do not have to travel over the reel and between the guide plate the risk of damage is reduced. For the same reason very few beans are carried over with the tines and the provision of a comb is unnecessary, although a rotating brush has been found to be an advantage. It is probable that this serves to remove clusters from the top of the tines. With the absence of a comb, the configuration on the reel can be improved, again increasing picking efficiency.

The following table uses figures not obtained at the same time, or in the same areas, and no attempt has been made to adjust them on a comparative basis. They can only give a general indication of the sort of result we would expect.

| | *Single row* | *Twin row* | *Forward multi-row* | *Rear multi-row* |
|---|---|---|---|---|
| Harvesting rate (acres/h) | 0.25 | 0.75 | 0.85 | 1.2 |
| Yield from Field (tons/acre) | 3.29 | 3.52 | 3.23 | 4.12 |
| Losses on Field (tons/acre) | 0.7 | 1.53 | 0.65 | 0.53 |
| Losses on Field (%) | 21 | 30 | 20 | 11 |
| Total Damage (tons/acre) | 0.38 | 0.46 | 0.98 | 0.43 |
| Total Damage (%) | 11.5 | 13.1 | 30.2 | 10.5 |
| Clusters (tons/acre) | 0.17 | 0.09 | 0.05 | 0.013 |
| Clusters (%) | 5.1 | 2.6 | 1.7 | 3.2 |

Some machines are fitted with cluster removers which is just another way of saying loss makers. Although these can be combined with cluster breakers and recovery units the complexity required to be built into the machine does not seem worthwhile. This is an operation which can more sensibly be undertaken on static machinery in the processors plant.

Removal of EVM by cleaning devices can be divided into two areas on a bean harvester. Leaf is very simple to remove using either blower or suction fans and these can be easily adjusted to give virtually no yield loss. Pieces of stalk and immature beans are much more difficult to remove using air cleaners as they more nearly approach the weight and air resistance of the beans and unless accurately adjusted can cause major losses or a very dirty sample.

The most successful systems appear to be those in which the cleaning area is the greatest possible to reduce crop density passing through the cleaner and where the natural flow of the product is in the same direction as the air flow, allowing a natural entrainment of the EVM while the beans fall clear.

We have now reached a stage where the harvesting rate of a single machine can exceed 6 tons/h and this represents the going rate of a medium size process line in a factory. When you consider the size and complexity of the cleaning plant installed at the factory it soon becomes obvious that the equivalent plant fitted to a harvester is impractical, particularly as it will operate at much lower utilisations. While no processor wants to handle excessive quantities of EVM of the balance between over complex field machines and a clean sample will required careful consideration in the design of future machines, particularly where these achieve even greater throughput.

## Conclusions

With both pea and bean harvesters the law of diminishing returns appears to be operating in effecting reductions in waste and damage as new machines are introduced. This is more marked in pea machines than bean machines possibly because of more intensive development. Greater emphasis is only likely to be placed on designing for waste reduction when the real costs of waste have been clearly quantified. This will only be achieved with considerable effort in mounting test programmes by independent bodies.

# The design and operation of potato harvesters for minimum damage and losses

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## Introduction

THE National Damage Survey[1] carried out in 1973 revealed that 21% of potatoes reaching the storage point did not meet the PMB Ware Prescription of that year. An earlier joint PMB/ADAS survey[2] showed that harvesters leave from 0.5 to over 1 tonne of potatoes in or on the ground. These two aspects of potato harvester performance – damage to potatoes, and losses – are influenced by a number of factors related to harvester design and setting.

Most harvesters used in United Kingdom have a similar basic design, consisting of a flat share, a continental web, either an elevating conveyor or a drum, a picking belt or automatic separator and either a direct delivery conveyor or a fast emptying bunker. One design is somewhat different in having a modified disc and spinner lifting system.

## The share

The majority of shares are flat and some are split into two or more sections to encourage the ridge to flow on to the web and to allow weeds and haulm to escape. Accompanying the share are static or rolling side plates. Sometimes the share is curved and side discs are replaced by torpedo shaped static plates. Whatever the configuration used, flat shares often suffer from a number of disadvantages: they encounter a wide variety of soil conditions and are influenced by soil moisture content, the presence of haulm, roots and weeds, and the slope of the ground. Certain combinations of these factors make this type of share difficult to operate, further compounded by failure to scour under some conditions. Petrov[3] suggests that soil will generally fail to move along flat shares tilted at an angle in excess of 24°, or if the length of share from leading to trailing edge exceeds 475 mm. In dry conditions, downward slope in the direction of travel may necessitate one-way harvesting, and in the same conditions, hairpinning of weed or haulm round the share and side plates can quickly lead to forward motion of the ridge often accompanied by spillage round the sides. A steady trickle of potatoes may be lost when this occurs. The most critical stage is reached when haulm or weed starts to jam on the side discs, hubs and scrapers. As soon as the side discs stop rotating, digging stops and the entire share throat becomes clogged; clearing the blockage is time consuming. On some continental harvesters the tendency to block is alleviated by fitting a ratchet drive to the discs from a crank arm driven by the harvester transmission.

Failure to scour, bulldozing, hairpinning and choking are all ills associated with flat shares in certain conditions, but what are the alternatives? Power driven disc shares for single row harvesters offer a number of advantages. A power driven disc digging head such as the one originating at NIAE and used on the SIAE dual web harvester has a pair of 560 mm discs mounted at an included angle of 67° and tilted forward to make an angle of about 22° to the horizontal. No side discs or special side plates are required with this arrangement. The draught of the share is lower than for a flat share – a major advantage in wet conditions where drawbar hp can be traded advantageously for pto hp. – Siepman and Weerd[4], who measured draught for various types of share, found a reduction of over 30% in draught for disc shares. The profile of the cut made by driven discs in the ridge approaches that indicated by Bailey[5] who determined the characteristic growth habit of potatoes in the ridge.

After four seasons of tests at SIAE, disc shares have proved reliable in a range of soil types and conditions. Jamming with stones occasionally occurs but is not a serious problem, so it has not been found necessary to spring-load the discs, though on very stony soils this could be beneficial. Weed and haulm present no problem and the high lift imparted to the ridge (11 in, 279 mm compared with about 5–8 in, 127–203 mm for a flat share) ensures that the front of the web is able to run more freely because it does not have to operate in a drowned condition. In the very wet conditions of the 1974 harvest a harvester with powered discs could operate when trailers were unable to move in the field. There are one or two disadvantages of disc shares which, though they should not be overlooked, need not be a barrier to their use. The bevel gearbox driving the shares transmits a fairly high torque and must therefore be robust, and a good chatter clutch should be used to protect the input shaft, however, suitable gearboxes and clutches are relatively costly. As discs wear, the gap between them increases and potato losses may occur, but hard facing applied to the disc periphery helps to combat the wear problem.

Apart from flat and power driven disc shares, other types are being developed. In Idaho, Johnson[6] has reported promising results with vibrating flat shares for two-row harvesters. The share vibrates at about 8–10 Hz with an amplitude of 38 mm. It is claimed that the parallel bars which are attached to the rear of the share promote good sieving with low spillage losses. If careful depth control is not exercised, however, there is an increase in the proportion of tubers which are not rolled aside by the leading edge of the share, but which are sliced through.

Automatic share depth control systems were introduced in the 1960s[7]. Typically a sensor wheel running on the ridge top alters the share depth through a hydraulic servomechanism, and the response of the system to changes in position of the depth wheel can be rapid and accurate. For gradual changes in datum height, the performance would be satisfactory, however, rapid changes in sensor wheel position tend to produce a response well ahead of the share in time and consequently the share, which may be about 600 mm behind the sensor wheel, is raised and lowered out of phase with the undulations. The results of a series of tests carried out to measure the response of the share to a cycle of displacements of the sensor wheel corresponding to ground undulations are given in Fig 1. This histogram shows the percentage of the time during a cycle when the share was either deeper or shallower than necessary. If the oil flow to the hydraulic ram controlling the share depth were restricted, for instance by throttling the pressure line, the response could be improved. There is evidence from research in Germany by Thaer[8] that the best datum for depth control would be provided by two sensor wheels running on either side of the ridge being dug. His findings suggest that there is a surprisingly large variation in depth of the lowest tubers along the row.

## The primary web

The continental web used almost exclusively on harvesters in United Kingdom, has not yet found favour in North America where improved heat treatment of link chain appears to be prolonging its use. The continental web is said to break easily on volcanic rock found in central USA although an alternative to the hook link web patented by Raybould is being used on a prototype low damage harvester in Idaho.

Whatever the form, the web is a major source of breakdowns and the principal site for damage to potatoes on the harvester. Experiments in Washington State, USA[9] and in the United Kingdom[10] show that damage is related to web speed, and work at SIAE[11] confirms that as ratio of web speed/ground speed widens, severe damage and damage index increases. It is vital to keep a soil cushion on the web, and this can only be achieved by careful

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*D McRae is from the Potato Crop Mechanisation Section, Scottish Institute of Agricultural Engineering.*

*Paper presented at the Autumn National Conference of The Institution of Agricultural Engineers, at Hotel Norwich, Boundary Road, Norwich on 9 November 1976.*

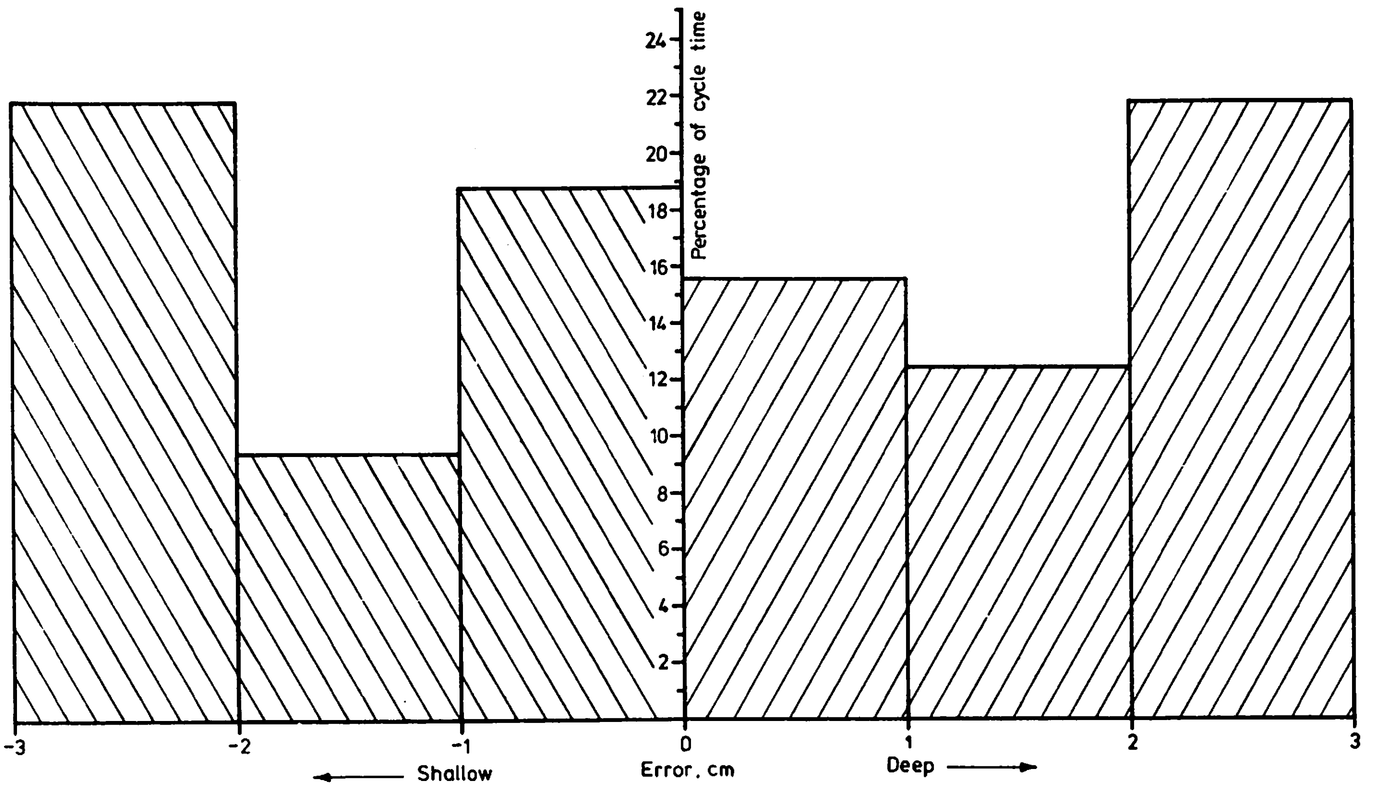


*Fig 1 Performance of automatic depth control. (Harvester speed 1.25 miles /h, pto speed 360 r/min*

matching of the web agitator size and number, the web speed and the forward speed of the harvester. A gearbox would be an advantage on harvesters if used intelligently, and the use of gearboxes to alter web/ground speed ratio is not new, some potato diggers were fitted with them in the 1930s, indeed, three-speed gearboxes are now fitted on some North American harvesters.

Palmer and McGechan[12] have shown that the drainage or riddling rate of soil improves, and damage to tubers is reduced, if the vertical accelerations produced by eccentric agitators are replaced by horizontal accelerations either normal or parallel to the web bars. Impact of potatoes on web bars is clearly also a source of damage. Tests at SIAE in 1974 showed that the mean drop height which could be expected to produce 50% severe damage in ten of the leading maincrop varieties was 613 mm when the impact surface was a flat plate, but only 180 mm on a web rod[13].

A potent source of damage in dry stony conditions is roll-back of material on the web. Large stones may cartwheel down the web if there is little soil cushioning and cause serious damage by collision with potatoes, while large potatoes may also roll down the web. A reduction in web slope can help, but may not be compatible with the harvester layout. Various combinations of flaps and rubber tines have been used to reduce roll-back damage, and anti-roll flaps travelling at the web speed, but mounted on a separate chain running above the web, have been used successfully on a prototype two-row harvester at SIAE.

## Dual web harvester

The dual web principle originally developed at NIAE offers a number of advantages over the conventional single web. According to the PMB surveys of 1972–74[14] over 61% by weight of maincrop tubers grown in Scotland were above 51 mm in size. The dual web arrangement (Fig 2) comprises an outer web with 51 mm spacing and a standard inner web with 32 mm spaces. The larger, damage prone, potatoes stay on the outer web, whilst the smaller potatoes pass through to the inner web. The outer web normally requires no agitation and damage by large stones on this web is reduced, thus damage levels determined by tests with a dual web harvester are lower than with orthodox machines in the same conditions. Apart from damage considerations, the other benefit of the dual web is the improved soil sieving ability. Enhanced sieving efficiency on the inner web follows from removal of all the large potatoes, stones and clods on the outer web.

## Haulm removal

Most haulm removers consist of either a wide link conveyor or a trapping roller – sometimes both are fitted. The former is effective for long haulm, but performs badly with short stems, roots and weed. Potatoes adhering to haulm may be lost at this stage unless a stripping roller is fitted, but this type of roller may wrap or ingest potatoes if hairpinning occurs. A haulm removing belt with a roller centre distance of 15 in (381 mm) has worked quite well on the SIAE dual web harvester. Wrapping does not occur while the greater area of contact provided by the two belts aids trapping of the haulm (Fig 2).

## Intermediate conveyors

The layout on most harvesters necessitates changes in direction and transfer of material from the web to another conveyor. The tail sprockets on the web are generally so positioned that a drop of 14–16 in (356–406 mm) is common at the transfer point. This drop can be reduced by using small idler rollers and moving the drive sprockets back from the transfer point. This simple but effective measure is used by Johnson on the University of Idaho Low Damage Harvester[15].

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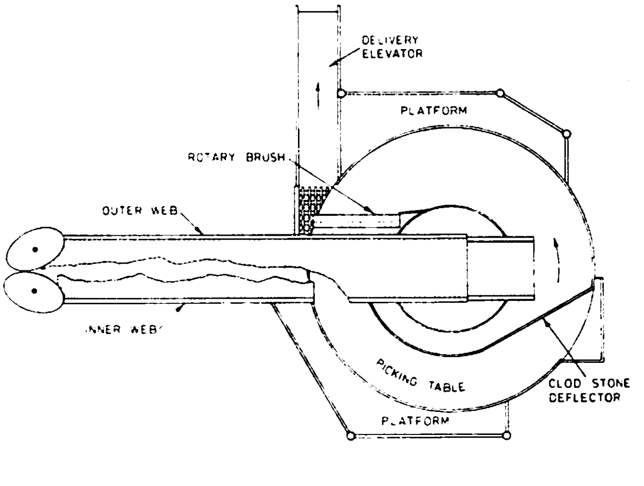
*Fig 2 the duel web harvester.*



## Separation

Fully automatic separation of potatoes from stones and clods will, for the foreseeable future, be accomplished in the field, or with un-manned harvester systems at the store, by x-ray separators. Work at SIAE has shown that a separator using x-rays from sources of the radioisotope Americium presents a number of difficulties. Though a measure of success can be achieved by using expensive photo-multiplier tubes, the cheaper Geiger-Müller tubes have not been sufficiently efficient. Apart from the high cost, the use of radioisotopes on a farm machine might pose a number of complex problems.

In conditions found in Maine and New Brunswick, where stones abound but clods are rare, harvesters fitted with air separators have been highly successful. In favourable circumstances they can give 96% overall separation efficiency though efficiencies down to 84% are reported[16]. Apart from an inability to deal effectively with clods, air separators require about 90 bhp (67 kW) to drive a 36 000 cfm (17 $m^3s^{-1}$) fan working against about 1.5 in (38 mm) wg. Stable separation has proved possible only in a negative pressure mode, so that any small pebbles or soil ingested at the separation plenum must pass through the fan. The more complex blade design needed for an efficient fan is not possible with the above configuration and all attempts to evolve a blower separator have failed.

Mechanical aids to pickers carried on the harvester such as sloping belts or rotary brushes give variable results and are sensitive to soil conditions. The SIAE dual web harvester takes advantage of the division of the incoming material into two size fractions, the pickers removing rubbish from the large objects and potatoes from the small ones, thus the number of objects picked per 100 tubers harvested is lower than for some comparable commercial machines (table 1).

**Table 1 Comparison between dual web harvester and three other types of harvester.**

| Actual rate of work ha/h+ | No. of objects picked/ 100 tubers harvested+ | % dirt tare+ | Leavings tonnes/ha+ | % severe damage+ | Damage index+ |
|---|---|---|---|---|---|
| SIAE | | | | | |
| 0.115 | 69 | 3.0 | 0.615 | 5.2 | 128 |
| Others + | | | | | |
| 0.104 | 83 | 9.1 | 0.785 | 8.6 | 176 |

*+ Mean for all sites.*

## Delivery into trailers

Severe damage attributed to the harvester delivery conveyor was reported in 9% of the case studies in the National Damage Survey. A survey of farms in East Scotland in 1971 showed that when trailers begin to fill, potatoes generally fall on the bare trailer floor from a height of 31 in (780 mm). It has proved possible to reduce this drop to 4.5–7 in (116–199 mm) with the SIAE automatic height control for delivery conveyors[17].

Unmanned harvesters warrant some comment at this stage for they introduce a further element in harvesting in stony conditions. The transport of potatoes mixed with stones is likely to produce damage, both in transit and on emptying at the store. The use of a sprung clamshell body trailer such as the SIAE cradle trailer could well reduce damage at this stage in harvesting. This type of trailer reduces shocks to the load during passage over rough roads and bumpy fields and allows minimum drop when the load is being emptied at the store.

## Conclusion

Damage to potatoes on harvesters can be attributed to incorrectly set shares, violent agitation on webs often accompanied by sharp angular stones and roll-back on bare web rods. Further in their passage through the machine they may be damaged by haulm removers, at transfer points, and finally, on dropping to a trailer or bunker floor. Improved share design, better depth control and radical changes in design of the web and its mode of agitation would help. Careful design of transfer points and automatic delivery conveyor height control would contribute to reducing damage.

Losses through spillage could decrease with the use of power driven disc shares, which would also lessen traction problems in wet seasons. There would seem little prospect of reducing losses of tubers which fall through webs since to decrease web spacing would bring a requirement for increasing agitation with the danger of more damage. Varieties which cling to haulm will tend to incur greater losses through haulm removers but the use of haulm stripping belts has proved effective.

Finally, if future harvesters are to have a high throughput with low damage and losses, it seems unlikely that this can be achieved by having the one person most likely to have the knowledge and ability to take action when a malfunction occurs, situated where he can neither see what is happening, nor hear above the tractor engine, evidence of jamming and clutches slipping. Though it may be some time yet before it gains general acceptance, the self-propelled potato combine of low profile, with driver advantageously placed to see all parts of the machine has appeared on the scene.

Well designed self-propelled unmanned harvesters are now in use in this country. There would seem to be a place for similar designs with provision for either fully automatic separation or manual separation.

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## Errata

IT is regretted that the following information was omitted from Vol 31 No 4 of *The Agricultural Engineer.*

A H A Abdel Reheem and M P Douglass, authors of "Effect of adjacent structures on farm building ventilation" are respectively –

Lecturer, Faculty of Engineering, University of Elmansourah, Egypt and

Lecturer, National College of Agricultural Engineering, (Cranfield Institute of Technology), Silsoe, Bedford.

In this paper there are errors in equations 1 and 2 which should read as follows:-

$$C_{p_t} = \frac{2\Delta P_f}{\varrho V_h^2} + \frac{\varrho V_h^2}{32\Delta P_f}\left(C_{p_W} - C_{p_L}\right)^2 + \frac{1}{2}\left(C_{p_W} + C_{p_L}\right) \quad \ldots\ldots (1)$$

$$C_{p_t} = \frac{1}{2}\left(C_{p_W} + C_{p_L}\right) \pm \frac{1}{2}\left[\frac{-64\Delta P_f^2}{\varrho^2 V_h^4} - \frac{16\Delta P_f}{\varrho V_h^2}\left(C_{p_W} - C_{p_L}\right)\right]^{\frac{1}{2}} \quad \ldots\ldots (2)$$

# Recent developments in potato storage


## W G Burton PhD


## Introduction

THIS paper does not match its title, in that it deals with old principles rather than recent developments. Universal application of these principles would make a far greater contribution to reducing storage losses than any recent development. Also the paper is concerned with storage biology rather than storage engineering, because it is the biological requirements which determine the storage methods. For example, the most efficient method of reducing a temperature gradient, rising from bottom to top of a stack of potatoes, would be to ventilate with cool air from top to bottom, drawing out the air through ducts beneath the potatoes. This, however, could lead to massive wet rotting, for reasons described below, from condensation of moisture on the cool potatoes at the bottom. The less efficient method of ventilating from bottom to top must be adopted.

Whether or not to store potatoes and how to store them are commercial decisions and, therefore, the technicalities of storage should not be considered in isolation. The technicalities must however, be understood and taken into account in making these decisions.

Cheap methods of storage can be quite efficient and are adequate in many cases. More expensive methods of storage must be justified by the resultant extra value of the crop, though, at present prices, methods which were not viable a few years ago can be justified.

There are two main outlets for stored potatoes, the ware market and the processing industry. The criteria by which ware potatoes are judged are size, shape and lack of blemishes due to disease or damage. Also the potatoes should be firm and unwilted and have good colour and texture. Flavour is not of great importance, although taints should be absent and the tubers should not be excessively sweet. This means a total sugar content of less than 1%.

Most of these criteria are independent of storage method, depending largely on variety, growing conditions and finally handling methods which may be linked to storage. Storage conditions play a major part in producing potatoes which are firm and unwilted and not excessively sweet, so storage methods for the ware market must fulfil these two criteria and also avoid losses of saleable weight by disease.

The criteria for the processing industry are similar in the need to avoid excessive trimming losses, wilting and sweetness. The difference in storing for the processor lies in the definition of sweetening. Sugar not only gives a sweet taste, but in the case of fried or roast potatoes is a main factor in the development of a brown colour in the product, which is thought undesirable by American and British crisp manufacturers. The content of reducing sugars should ideally not exceed 0.1%, but passable results are obtained up to a content of 0.25%.

Discussion of the principles of potato storage must thus concentrate on three things — disease control, physiological shrinkage, largely due to water loss, and changes in sugar content. Nationwide losses during storage may well average 15 — 20% of which 10 — 15% is due to disease and 5% to physiological shrinkage. Evaporation may account for two thirds of this shrinkage.

## Disease control

This can make the biggest impact on the reduction of storage losses and it is the loss most susceptible to control if only for the reason that it is not uniform from year to year and farm to farm. For example losses recorded in a survey varied from about 2% in Majestic potatoes stored for 6 months on one farm to over 68% in the same variety stored for little more than 2 months on another. The national mean loss in the same survey was 15% thus demonstrating the potential for considerable reduction, down to 2%, in losses.

Local weather differences can play a part, but large losses are usually the result of malpractice in either culture or storage. The major causes are either the inclusion of excessive numbers of blighted tubers in the store, or conditions which encourage bacterial wet rots.

Blight control is not a function of storage, but the avoidance of bacterial wet rots is. Wet rot organisms are present on or in the tubers, but need not penetrate the cells to cause breakdown. Such penetration can occur if the cells are damaged by exposure to anaerobic conditions or by coming into contact with chemicals, such as sprout inhibitors.

Anaerobic conditions do not exist even in a large unventilated mass of potatoes, but individual tubers can become anaerobic if they are covered with a film of water, for a few hours. Gaseous exchange through the pores of the skin of the tuber is interrupted by the film of liquid. The oxygen in the tuber is used and cannot be replenished, and carbon dioxide builds up, leading to aberrant cell metabolism and eventually breakdown. The symptom noticed in practice is the occurrence of bacterial wet rots. The inclusion of wet loads in the store can lead to these conditions. Potatoes lifted from wet soil do not present a storage hazard, but loads subject to heavy rainfall whilst in the trailer do.

Sprout inhibitors are a hazard if they are in contact with living cells. The skin of the tuber consists of dead cork cells which the inhibitor will not harm, but if it contacts unhealed harvesting wounds damage can be caused followed by bacterial invasion and rotting. Harvesting wounds are more often associated with fungal wound parasites which are always present on the tuber, but cannot penetrate the skin, and the first priority in storage is normally to heal wounds before invasion occurs.

The rate of wound healing depends on temperature, atmospheric composition and humidity.

Temperature is most important in practice. At 5°C signs of healing will not be found in under two weeks compared with 3 or 4 days at 10°C and 1 or 2 days at 20°C, which is favourable for wound healing, but also favours water loss, break of dormancy and rotting organisms. 5°C is so unfavourable for wound healing that it allows fungal invasion even though it is well below the optimum temperature for the rotting organisms. Temperatures between 10° — 15° C for about two weeks at the start of storage are usually adequate. Relative humidities of less than 50% inhibit healing due to drying out of the exposed tissue. Relative humidities of 100%, or near, inhibit healing by causing proliferation of the wounded surface instead of suberisation. 80 — 95% relative humidity is optimal.

The composition of the atmosphere is of little practical importance. A reduction of oxygen concentration of 10% has little effect although anaerobic conditions inhibit healing. An increase of carbon dioxide concentration to as little as 5% has a marked inhibiting effect.

## Water loss from potatoes

This is very simple in theory but the effects of practical management can be complicated.

Water passes through the dead cork cells of the tuber as through a wick and then evaporates. The rate at which this happens is proportional to the amount of water the air can hold before it is saturated. The drier the air the faster the evaporation. The dryness or evaporative potential of the air in terms of its water vapour pressure deficit can be measured in millibars. An approximate evaporation rate for mature well healed potatoes is 0.1 to 0.15% per week per millibar deficit in the surrounding air. Freshly harvested immature potatoes can have a rate of 10 times this and even mature tubers lose 0.5% per week per millibar in the first week before healing has taken place.

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*Retired Director of Food Research Institute, Norwich.*



*Paper presented at the Autumn National Conference of The Institution of Agricultural Engineers at Hotel Norwich, Boundary Road, Norwich, on 9 November 1976.*

The rate increases in sprouting potatoes since evaporation from the sprouts is rapid.

There are two methods of reducing evaporative losses. The first is to ensure the tuber itself is as little liable to loss as possible, by being mature with healed wounds and no sprouts. The second is to ensure that the air in contact with the tubers is as humid as possible without risking condensation on the cooler tubers. Humidification can be achieved by steam or water injection into ventilating air or by humidity build up by re-circulation. Management, too, must take account of the effect of a temperature gradient upon the water vapour pressure deficit of the air in the stack.

Without humidification, evaporative losses of 5% by the end of March might be expected. With it the loss may be reduced to 1 or 2%.

## Changes in sugar content during storage

The quality of potatoes in store cannot be maintained for more than about 9 months with some variation according to variety and sample.

Coincident with the start of sprout growth the rate of conversion of starch into sugar begins to increase.

If sprouting occurs normally most of the sugar produced goes to building up dry matter of the sprouts, but there is some increase in the sugar content of the tuber, although this is small at first. As time goes on the rate of sugar production exceeds the rate at which it is used in sprout growth and sugar accumulation finally makes the potatoes unusable. At present this cannot be prevented and suppression of sprouting only increases the rapidity of sugar build up, since sugar formation is not dependent on sprout formation but coincident with it, and without growing sprouts there is no 'sink' for the sugar formed.

This form of sweetening is known as "senescent sweetening" and is quite separate from low temperature sweetening. Potatoes for processing must never be subject to low temperatures, that is temperatures much below 10°C, because although low temperature sweetening may be reversed by raising the temperature to 20°C, the results are not uniform, and there are associated hazards.

Temperatures of 10°C are, however, too high for prolonged storage since senescent sweetening will appear sooner; also spread of disease and water loss are favoured.

Long term storage for processing necessitates precise uniform temperature control in the range 7° to 8°C, a compromise between sweetening due to low temperatures and that due to senescent sweetening.

This can be achieved in bulk stores by prolonged positive ventilation through the potatoes — at least 12 hours per day at 7°C at a rate of 0.6 metres$^3$/min/tonne (20 ft $^3$/min/ton) or, for storage in 1 to 2 tonne boxes, air at 7°C should be circulated around them continuously at about 0.3 m$^3$/min/t.

The normal patterns of temperature distribution in bulk unventilated potatoes do not matter for ware potatoes — the temperature range is about 1.8°C for every metre of height — and ducts may not be necessary except for introducing sprout depressants, provided storage is not to a height exceeding about 2.5 m and is not prolonged into hot weather. Sophisticated systems for providing uniform conditions are extravagant for ware potatoes, but contracts for processing mean precise control of conditions and careful day to day management to meet the requirements.

Time limits the discussion of other possibilities such as alternative chemical sprout suppressants, sprout suppression by irradiation or controlled atmosphere storage, using normal oxygen levels, but scrubbing out $CO_2$ and allowing other volatiles to build up.

Continuing high prices may make the last two worthwhile in the future.

# The waste makers Edited summary of discussion

1 **Mr C Baskerville** (ADAS, Norwich) asked:—

a) What is an acceptable loss for sugar beet? Perhaps 2%?
b) Should farmers measure beet losses and if so, how?
c) Belt lifters appear to cause least loss. Is this due to acute seeking?
d) Continental machines use shares, UK machines lifting wheels. Should UK manufacturers be producing machines fitted with share type lifters?

**Mr Hearn** in reply said that acceptable beet losses depend on the prevailing soil condiions. Half to ¾ ton/acre is reasonable in "normal" conditions, but impossible to obtain in bad conditions.

Secondly if farmers can measure accurately they should be encouraged to measure losses. But farmer estimates tend to be subjective, for example in trailer loads/acre. If they cannot measure accurately they should leave the job to Corporation field staff, who will also advise on the best machine settings.

On the matter of lifters, perhaps the questions should be .... "do self-seeking shares or the belt type lifter cause lowest losses?" It is cheaper to use self-seeking shares than controlled seeking. In the UK self-seeking shares would do as good a job as any mechanism. There is no doubt that lower losses are obtained with self-seeking or controlled steering shares than with belt type lifters.

**Mr Maughan** commented that the weakness of the belt mechanism in frosty conditions was well known, but that one should not read too much into values of losses as such.

2 **Mr I Gedye** (Harper Adams Agricultural College) referred to the cost effectiveness of improved machine design in relation to crop losses and wondered whether manufacturers needed to do more evaluations on costings. In reply, **Dr Busse** said that cost effectiveness varied according to geographical location. He suggested that automatic aids such as self steering for maize combines were becoming more economical because of their low cost relative to machine price.

3 **Mr D J Bottoms** (NIAE Silsoe) commented about operator/machine relationships.

Designers should consider the operator and the machine together, he said, and try to match their performance characteristics. Warning devices should also be matched to the operator's task.

A diagram (Fig 1) illustrating the way the brain works was shown. Mr Bottoms continued: the brain is a single channel system; it does one task at one instant and switches rapidly from one signal to another, trying to match effector output to sensor inputs. It is understandable from this how easy it is to overload the human system, and why we should consider the interactive effect, not just the man or the system.

**Dr Busse** supported Mr Bottom's plea. He quoted an example of a big truck manufacturer who had researched his operator seat very thoroughly and developed a perfect suspension system, but it was no good because the operator could not reach his controls as he was always in a different position!

4 **Mr C Culpin**(AEA, Silsoe) said potato harvesting losses had been reduced recently, and asked Mr Theophilus the date of the data quoted in his paper. **Mr Theophilus** replied that 1972 figures had been used.

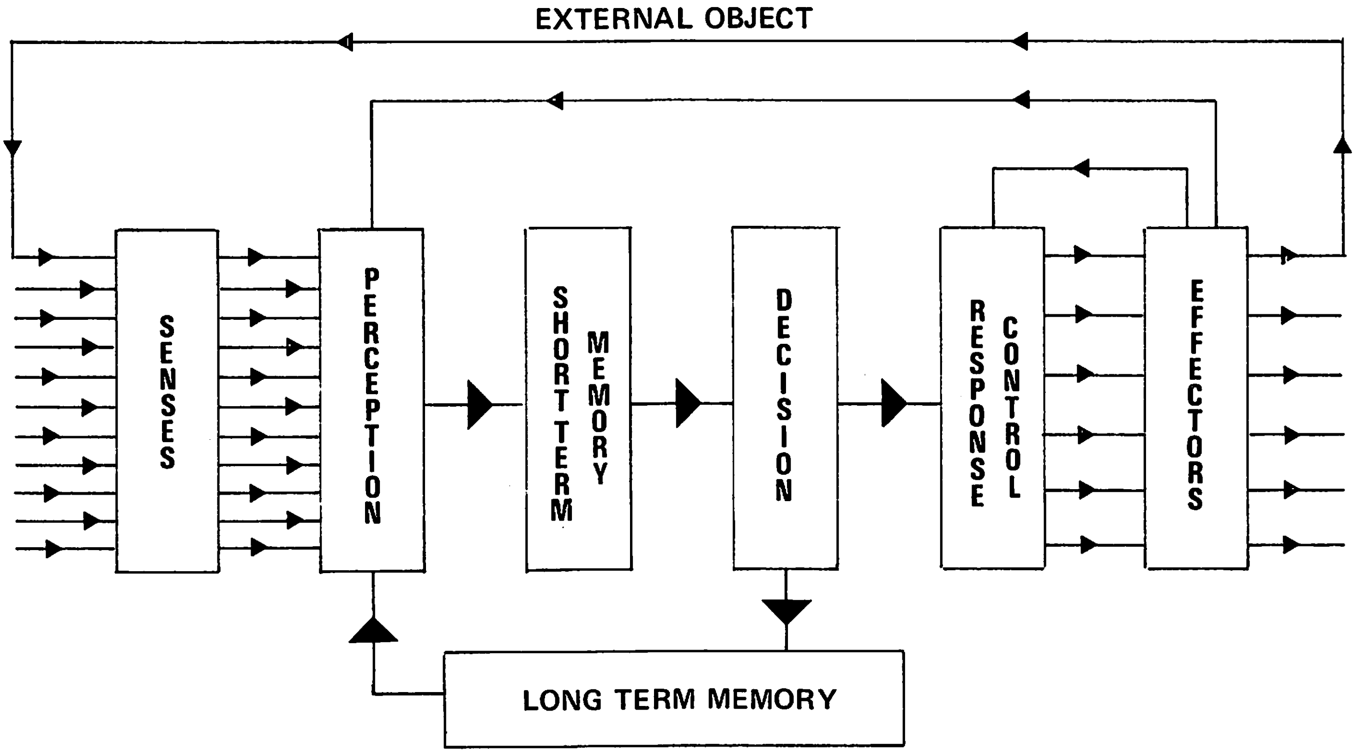
5 **Mr J Tullberg** (NCAE, Silsoe) asked:—

a) Are grain loss sensors being fitted by combine manufacturers?
b) If so at what price?
c) How frequently are the monitors calibrated?

**Dr Busse** commented that Claas was the only manufacturer offering its own loss monitor on combines. The UK importer had decided not to offer the monitor in this country. The price of the monitor would be £400 in the UK. Calibrations of the monitor should be carried out between varieties or between crops, and for different crop densities.

[Manns Monitor states that Manns RDS Mk 4 OEM will be fitted as standard equipment on all Dominators marketed in UK, 1977 — Ed]

6 **Mr T C D Manby** (NIAE Silsoe), referring to current research at the NIAE on beet topping knives observed that it was almost impossible to keep the knife sharp irrespective of steel quality. A knife with a double chamfered edge showed some improvement over a conventional design. He went on to suggest that topping could be done by a wire instead of a knife but that there were




development problems. Another possibility being considered at NIAE was to pick up as much soil as possible with the harvested beet, which seemed to work. Transportation off the field was a problem and he asked about the relative importance of improved transport systems. In reply **Mr Hearn** said that the success of harvesting beet with large amounts of soil was dependent on soil conditions — it was not too bad if the soil was either wet or dry but deteriorated in between these conditions. Excess soil with the beet caused the factory to stop.

7 **Mr P Seligman** (Lodge Farm, Harleston, Norfolk) asked:— Are we right not to have whole beet delivered to the factory and topped there? We must produce more sugar: topping is a major problem. The **Chairman** seconded Mr Seligman's point and said that whole beet was delivered to factories in Russia.

**Mr Hearn** commented that the continentals, who accept lower standards of topping than we do, would like to get up to our standards. From the factory point of view, if crown impurities were present the cost of extracting sugar was very much higher. If we lowered topping standards the factories would be brought to a standstill, so there was no question of doing this.

Pursuing his argument, **Mr Seligman** felt that we need to rethink this problem. Why not top in the factory rather than in the mud?

**Mr Hearn** suggested it was easier to adjust a topping unit in the field than to alter a factory process.

**Dr Busse** said that it cost 25 pence to extract the sugar from 1 ton of beet, while the cost of man and machine in the field was four times this figure. But factories in Germany claim that machinery manufacturers should do more work on the higher investment in their products.

8 **Mr A J Gane** (PGRO) talking about the pea crop, suggested that a contribution to lower harvesting losses would be the growth of "leaf-less" varieties having stiffer stems and more upright form. Referring to dried peas, he said that losses due to staining were mainly caused by weather conditions rather than disease.

**Mr Seligman** thought that other losses might be increased when there was less green material in the swath.

In reply **Mr Bain** said there was a case for believing that this might happen. But as the performance of pea pod pickers was limited by the amount of vine in the drum, the use of plants producing less vine might be advantageous. With less vine, speed was the limiting factor. He suggested that losses increased at over 5 mph.

9 **Mr J W Whitsed** (Root Harvesters Ltd) said that the size of the problems for potato harvester design with reference to waste in comparison with sugar beet harvesting were that 300 tons of soil were lifted per acre with a 13 ton crop, that potatoes were grown on any soil type, and that soil conditions could vary from ideal to very poor. He concluded that higher losses for the potato crop were not surprising. **Mr McRae** agreed but thought that as much as 600 tons of soil/acre had been reported. An added problem was the ratio of clods to potatoes which could be as high as 25 to 1.

10 **Mr A Morris** (Hall Farm, Wickmere, Norwich) supported Mr Whitsed's point. He asked how often were we able to harvest potatoes in good conditions? Manufacturers tried to keep costs down, but one useful principle would be for each element of the machine to have its own speed control in order to achieve better separation.

**Mr McRae** agreed that this would be an advantage, but that there would be too many adjustments on the machines. The incorporation of a web speed/ground speed ratio meter might be advantageous, however, and would be feasible.

11 **Mr R A Den Engelse** (East Anglian Real Property Co Ltd) wondered if row widths greater than 36 inches would reduce losses for potatoes. **Mr McRae** felt that he was not fully qualified to answer the question but suggested that there must be a limit on row width increase. For a two row harvester a change in row width could cause design problems.

12 **Mr J Kenyon** (Mather and Platt), commenting on pea vining, said that plastics coated screens were an improvement. They did still block though they could be cleaned with a rotary brush. He thought that using "leaf-less" pea varieties would move us towards picking rather than cutting the crop. In this case a lack of leaves and hence the absence of a cushion might be a disadvantage.

13 **Mr J C Arnott** (Agricultural Training Board) said that both operators and farmers needed training to improve their performance and motivation. Commenting on this **Dr Busse** said that manufacturers had a responsibility for training both farm operators and dealers' staff. Referring back to the comments on row width Dr Busse suggested that there was an "agro-biological" effect and said that with maize rows of 30 inches were too wide.

14 **Mr M Flannery** (Rycotewood College) asked if the presence of a cab on a combine isolated the driver, thereby causing increased grain losses and creating a need for expensive loss monitoring equipment?

**Dr Busse** said that there was no relationship between the cab and the grain loss monitor. He thought that the use of the monitor made sense with or without a cab.

**Mr Bottoms** commented that since the introduction of "Q" cabs operators were feeling more isolated because of the general reduction in noise level. **Dr Busse** remarked that a lot of money had been spent to isolate operators from noise, but then they installed a big radio and brought the dB(A) back to 90!

**Mr Bottoms** said that the driver isolation experienced in "Q" cabs was sometimes associated with a feeling of insecurity because these cabs tended to be higher above ground level than earlier models. He went on to suggest that the use of radios by tractor drivers might be an indication of the monotony of the task, particularly in large flat fields.

**15 Mr R Filby** (J Mann & Son Ltd) said that grain loss and other functional monitors were important since they could provide an indication of a malfunction several minutes before the operator might otherwise become aware of the problem.

**16 Mr Baskerville** (ADAS) asked **Dr Burton** whether or not he would recommend the installation of ducts for ventilating potatoes stored at a depth of less than 2.5 m, bearing in mind the harvesting conditions of 1976?

**Dr Burton** replied that ducts do not help to dry the crop, convection does that. But he would not have stacked bulk potatoes so high. Even ducts will not help if a wet load goes into store. **Mr Baskerville** said that a considerable quantity of the crop was stored at 8 ft depth (2.4 m) with ducts; was this necessary? **Dr Burton** commented that having a fan and ducts was an insurance policy, often paid for a long time before it became necessary. Many Yorkshire farmers store at a depth of 3 m without ducts and suffer no great losses. In bad seasons ducts will not help.

**17 Mr A Morris** referring to pea harvesting and previous discussion of "leaf-less" varieties asked whether pea haulm collection from present machines was economic or should it be a waste product. **Mr Bain** said pea haulm silage was economic but drying was not economic. The "leaf-less" varieties were not yet used commercially. Pea pod pickers would not necessarily reduce the amount of waste.

**18 Mr B Taylor** (Mather and Platt) asked whether the use of leafless varieties would cause more stone removal problems in pea pod pickers. **Mr Bain** thought they probably would. Processors would not like it, but it might be inevitable.

**19 Mr T Munro** (Student, Rycotewood College) asked whether manufacturers of large machines should provide operator courses or whether it should be the responsibility of dealers. **Dr Busse** replied that courses are run for owners, drivers, mechanics etc. **Mr Munro** then said that since maladjustments still occurred perhaps this reflected insufficient courses or that they were poorly attended. **Dr Busse** said that this was not necessarily the case and that there could be a fault which might be more easily detected by the use of monitors.

**20 Mr P Seligman** said he thought that combine operators were reluctant to get off the machine once inside the cab. He had heard that a helmet fed with fresh air was to be put on the market, and perhaps this was a better idea than a cab. **Dr Busse** said such a helmet was available in Germany, but the man could not move. He added that the best working arrangement is obtained by providing sufficient trailers to keep the operation going continuously, avoiding the necessity for the driver to get out of the cab.

[A helmet with battery powered air filter is now available. — Ed]

# CORROSION IN AGRICULTURE

THOUGHT to be the first conference in the United Kingdom devoted entirely to corrosion in agriculture, this meeting was arranged by the Institution in association with the Committee on Corrosion of the Department of Industry.

The East Midlands Branch were the hosts on this very successful occasion, held at the University of Nottingham on 11 January. Nine papers were given, the speakers coming from the academic world, from production and marketing sides of industry, from advisory organisations and from agriculture itself. The conference chairman was Dr D N Layton, chairman of the Committee on Corrosion of DoI.

Abbreviated versions of the available papers are given here. Regrettably time and space limitations allow only an abbreviated version of the discussion.

Copies of the full papers and a summary of the discussion may be obtained from Miss J Glanville, Corrosion Secretariat, Department of Industry, Room 540, Abell House, John Islip Street, London SW1P 4LN. No charge is made.

# Corrosion : what is it — what does it cost ?

**P J Boden**

FOR engineering purposes, iron is one of the most remarkable of materials. By combining it with carbon to form alloys (the steels) one can obtain, relatively cheaply, the most versatile set of properties of any material available to the engineer. It is cheap because large quantities of its ore are available in almost all parts of the world.

Practically all metals available to the engineer exist because of a thin skin of metal oxide which protects the metal from further oxidation. Corrosion of metals depends therefore on the strength of the oxide film and corrosion can occur if the film dissolves (rust) or if it is broken by wear (erosion) or by bending of the metal (corrosion fatigue). That this is easy to do is not surprising since metal oxides are brittle compared to the metal. It is possible to protect this oxide in a variety of ways.

Under certain atmospheric conditions, ie normal temperatures under dry conditions there is no corrosion. Oxygen and water are required and in the damp atmosphere of many parts of the world a weakening of the oxide film occurs by the relatively high humidity. In an industrial atmosphere the emission of sulphur dioxide results in acidity, absorbed in the droplets of water carried into the atmosphere which deposits on the metal surfaces as sulphuric acid and dissolves the metal and its oxide. Aluminium, stainless steels, zinc, titanium, copper, all form these protective oxide films but they are generally more protective than the oxide films on iron.

It is in principle comparatively easy to allow for uniform corrosion; a pipe wall or a tank wall is made thicker. However in some circumstances highly localised attack occurs to form small isolated pits over a surface which can lead to a small hole which allows leakage. Combinations of corrosion, tensile stress, and vibrations can often lead to cracking. Excess stress may be inadvertently designed into a structure to give a stress raiser, giving two or three times the overall stress. In the presence of a corrosive environment this can lead to a crack forming, which further intensifies the stress resulting in cracking to destruction. Stainless steels are prone to this when cleaned in hot hypochlorite solutions used for sterilising.

## Costs

The Government enquiry into the 'Costs of Corrosion' (prepared by a Committee under Dr T P Hoar) found that in 1971 the estimated losses due to corrosion in the UK exceeded £1 300 million per annum. The enquiry did not cover all industries and for instance the Agriculture industry was not included. The correct estimate is therefore probably in the region of £2 000 million.

The Committee also estimated that £310 million could be saved by applying what we already know about corrosion prevention. Thus there is a need to increase the awareness amongst engineers of the preventive methods that already exist. Because of this lack of awareness many industries are effectively exporting corrosion to their customers when they sell their products.

The true cost of corrosion cannot always be calculated by allowing for replacements and maintenance. The unplanned outage or failure and safety aspects are now important occurrences which must be taken into consideration when allowing machinery to work whilst it is badly corroded. The Health and Safety Act is having a severe impact on industry. The importance of corrosion in this respect lies in the fact that a very large proportion of mechanical failures, breakdowns, and unsafe conditions arise because of corrosion. The Act allows not just the manufacturer but the individual to be held responsible for injury arising from shortcomings in design and manufacture.

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*P J Boden is of the Dept of Metallurgy and Materials Science, University of Nottingham.*

The advent of the European Economic Community also appears likely to lead to a change in the relationship between the individual and his product in that continental law holds the professional engineer personally responsible for his actions and claims for damages resulting from professional negligence can be frighteningly large. The professional engineer should be more aware of means of minimising corrosion and the economic advantages of doing so.

Corrosion awareness at the technician level is also of importance in connection with the proper application of corrosion prevention measures, proper installation and proper maintenance. The incorporation of aspects of corrosion into ONC and HNC courses and into other courses must be given serious consideration.

# Designing against corrosive materials in silage and slurry

B E Randall

## Silage

THE most acidic and corrosive environment in tower silos is found with whole crop maize silage, which at 20—25% dry matter ferments readily, and rapidly produces total acid contents that can represent as much as 10% of the dry matter. Typically this can give concentrations in solution of 2.0% lactic acid and 0.5% acetic acid with a pH as low as 3.6.

In the presence of oxygen, secondary fermentation can take place after which the silage contains predominantly butyric acid. This has a characteristically bad smell, does not dissociate readily and as such is a very weak acid. Thus secondary fermentation will lead to a substantially higher pH, and for this reason it is essential to carry out pH determinations of silage samples within hours of removal from the silo.

The speed of a chemical reaction between steel and silage acids will depend upon temperature, the concentration of dissociated ions in the effective electrolyte and the rate of removal of any insoluble products of corrosion which might otherwise form a barrier to further attack.

Due to the initial exothermic fermentation process, temperatures inside a silo can be as high as 30°C. Since most bimolecular reactions have a Q10 = 2.0 (ie the velocity of reaction doubles for a 10°C rise in temperature) the rate of corrosion inside a silo can be twice as fast as outside.

## Slurry

The main corrosive component of most farm slurry is urea; but anaerobic fermentation can lead to the production of substantial amounts of ammonia and its associated salts. The use of high nitrogen rates on grassland can lead to traces of nitrate in the slurry, much of which undoubtedly finds its way there from wasted feedstuff.

As with many other corrosive liquids, the greatest corrosion potential seems to occur near the surface. Work with liquid fertilizers has shown that the greatest corrosive effect occurs with solutions containing about 15% nitrogen. Greater corrosive effects have been noted when half the free nitrogen is available from urea and half from ammonium nitrate. Free ammonia can tie up corrosion inhibitors such as orthophosphate and can prevent passivation of exposed metals.

Although nitrogen concentrations in slurry rarely reach these levels, the free nitrogen ions in solution are made available from a cocktail of urea, ammonia, and ammonium salts, a perfect combination for corrosive disaster.

## Prevention of corrosion of silage towers and slurry tanks

Although the chemical reactions between silage juices and steel, and slurry and steel are somewhat different, they both constitute highly corrosive environments and with long term investments such as silage tower structures and slurry tanks there is only one real answer and that is to interpose an inert material between the stored material and any corrodable materials forming the storage structure.

Vitreous enamels are extremely durable glass, fused to metal at high temperature. They provide one of the best means of preventing metal from corroding and at the same time leave a surface which is easily cleaned and maintained and can be made pleasing to the eye. This protective coating should not be confused with organic stoved finishes which are sometimes called enamels.

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The cost of vitreous enamelling a piece of steel is not greatly different from high grade painting processes which also involve degreasing, shot blasting, preparative pickling, undercoating and dipping and stoving.

A vitreous enamel coating is probably the best for both wear and chemical resistance, being both hard and inert. In use the main danger is chipping.

Hot-dip galvanising has consistently proved superior to all other coatings for other structural members not exposed to the corrosive contents. Sheradizing, cold spraying and electro-plating using either zinc or cadmium do not match the life of the enamel structure.

Plastics coating gives perfect protection but is liable to surface damage and, once penetrated, the conditions created are perfect for crevice corrosion, with rapid loss of adhesion between the plastic film and metal. Additionally there may be no outward sign of deterioration, a dangerous situation in the case of structural members and safety equipment such as hand rails etc.

The use of galvanising techniques on components exposed to silage juices or slurry is not very effective, for although the rate of corrosion of zinc in such electrolytes is about one fifth to one tenth that of mild steel, the rate is still high enough to remove a .010 inch coating within six months and leave the steel unprotected.

## Corrosion and wear

The most intractable problem occurs with components subject to high wear rates and a corrosive environment.

Components which operate under cyclic or fluctuating loads may eventually suffer a fatigue failure. When fatigue loading and a corrosive environment are combined, the resulting problem becomes more severe than when the two effects are separate.

If the fluctuating stresses in a component are high enough to initiate small surface cracks at stress concentrations, then anodic reactions may be set up within these cracks and cause them to propagate more rapidly through corrosion. Alternatively the stresses may be so low that fatigue cracks would not normally occur but the corrosion may be more severe and at regions of local attack on plate surfaces cracks may initiate and propagate, even at lower stresses.

Unlike stress corrosion, which usually only occurs in specific environments, corrosion fatigue may occur where any fatigue loading and corrosive conditions exist.

At the bottom of a silo filled with chopped grass, densities can reach the order of up to 70lb/ft$^3$. The loading on the active components of the cutting and unloading equipment is extremely severe, similar in fact to the loading experienced by coal cutting machinery. Like coal cutting equipment, many of the working parts work unlubricated with chains etc, immersed in the cut material. Unlike coal cutting, however, the corrosive environment can be severe.

Unlubricated scuffing steel surfaces working at high unit pressures demand the use of low-alloy steels capable of being case hardened to values in excess of 60 Rockwell C and on fast wearing parts requiring a hardened depth of the order of 0.040 inches.

These requirements rule out the use of standard austenitic stainless steels of 18% Cr, 8% N, 2% Mo type where hardness values in excess of 50 Rockwell C are difficult to obtain.

This really leaves only one choice — case hardening steels.

However most alloy steels held for prolonged periods above 800°C develop a very coarse grain structure in the case and exhibit much higher rates of corrosion in silage juices than fine grained structured steels.

Refining for extended periods at 760°C and quenching gives a fine grained martensite structure in the surface case.

One of the most valuable features of a case-hardened component is that the carburized case is generally in a state of compression which leads to an appreciable gain in fatigue strength.

The final grinding of carburized components is an operation which requires great care if grinding scorch or cracks are to be avoided. A soft wheel with a light cut and ample coolant should always be employed.

A form of stress-induced corrosion has also been noted in silage silos around heavy interference fit joints and, on cold forged areas with residual stresses.

# Ways of minimising the corrosivity of propionic acid

Dr D Berry

PROPIONIC acid, a liquid aliphatic acid, inhibits the development of a wide range of micro-organisms including those responsible for the spoilage of many foodstuffs and agricultural products. The agricultural uses of propionic acid were pioneered by BP Chemicals Ltd in the late 1960s, and these have made a worldwide impact on the storage and handling of feed grains on farms.

In the conventional farm treatment, as freshly harvested grain enters the auger, propionic acid is sprayed over the exposed flights. Use is thereby made of the mixing action of the auger to achieve a good distribution of the relatively small volume of preservative throughout the grain.

Propionic acid has also been used, to a lesser extent, as a mould suppressant for hay. In this case the acid is usually applied as the hay is being baled.

## Corrosivity of propionic acid

In common with other aliphatic carboxylic acids, propionic acid is corrosive towards certain metals. Results from corrosion tests involving immersion of metal test pieces in concentrated propionic acid are presented in table 1.

**Table 1 Rates of Corrosion of various metals immersed in propionic acid at ambient temperatures and in moist barley (20% mc) freshly treated with 2% propionic acid.**

| Metal | Corrosion rate in acid (mm/year) | Corrosion rate in treated barley (mm/year) |
|---|---|---|
| Stainless steel (845 Ti) | 0.005 | – |
| Aluminium | 0.006 | nil |
| Brass | 0.011 | – |
| Copper | 0.017 | – |
| Zinc | 0.060 | 0.010 |
| Mild steel | 1.30 | 0.037 |
| Galvanised steel | – | 0.011 |

However, in practice, during application on an auger or baler, the contact time for acid on metal is extremely low, leading to much lower corrosion rates than those quoted. This has been borne out by experience ever since the acid has been used to preserve grain, in that farm augers and other equipment have not suffered.

Because of its solvent property, propionic acid can create more of a problem through the ease with which it strips paint from metal surfaces. The exposed metal is then vulnerable to normal atmospheric corrosion and requires some form of protection.

Turning now to concrete, an unrendered surface because of its alkalinity will be slightly attacked by propionic acid. In practice, such attack can occur during the storage of propionic acid treated grain in concrete bins. However, to put matters in perspective, it should be noted that such attack is noticeably less than that of silage effluent.

## Corrosion protection

There are a variety of ways in which the corrosiveness of propionic acid can be minimised. For equipment such as augers it is good working practice to remove all acid-treated grain after use, and wash out with water. Applicators should be similarly cleaned. The results presented in table 1 indicate that the order of preference for constructing metal storage bins is aluminium >galvanised steel > mild steel.

There is no need for protective coatings when aluminium bins are used. When galvanised steel bins are used for storage, the use of protective coatings such as silicone based paints, chlorinated rubber paints, or an epoxy resin finish is recommended.

Protection of concrete surfaces can be accomplished by either covering walls and floors with clean plastic sheeting, or painting surfaces with an acid resistant coating such as chlorinated rubber or epoxy paints. The coating should be resistant to both organic acids (specifically propionic acid) and alkali (concrete surface). Such practices are also required to prevent moisture and rising damp from migrating into the treated grain.

The use of inhibitors may be considered but these have the disadvantage that each system needs to be tailor made to suit a particular application and environment.

Recent research by BP Chemicals has shown, that it is possible to reduce the corrosivity of propionic acid without significant loss of preservative activity. This has been achieved by adding a cation to aqueous propionic acid in an amount which is less than the chemical equivalent required for full neutralisation. One such formulation is marketed by BP Nutrition (UK) Ltd as Add-H.

A major advantage of these acid salt solutions is that in practice they do not remove the paint film from machinery (eg hay balers), so that neither the solution nor the weather cause deterioration of equipment.

The solutions are also less corrosive than aqueous propionic acid to bare metal as is illustrated by immersion tests.

The acid salt solution has also a lower vapour pressure than the free acid, and odour and evaporative loss are virtually eliminated. Such a property is particularly advantageous in the treatment of moist hay, where evaporative losses of volatile additives can be encountered. The acid salt solution is not corrosive to skin.

*Dr Berry is of B P Chemicals, Hull.*

# The resistance of steel to corrosion

K A Chandler

## Introduction

GENERALLY, corrosion is not a major problem in agriculture because it can be controlled by the application of suitable coatings. Many of the products available from British Steel Corporation are inherently corrosion-resistant, eg stainless steels, organically-coated strip and galvanised sheet. However, to obtain full benefit from these products it is necessary to examine the general design of the building or equipment from the standpoint of corrosion. It is not generally satisfactory to design plant or buildings and then to consider methods of protecting them from corrosion.

## Factors influencing corrosion of steel

Bare steel will corrode whenever it is exposed to an environment containing oxygen. The atmospheric conditions on the outside of buildings will vary considerably. Most farm buildings are in fairly clean areas so, generally, the conditions are not particularly corrosive. Industrial pollutants, such as sulphur dioxide, have a marked influence on the corrosion rate of steel, and buildings and equipment near industrial centres are likely to require a higher degree of protection than those sited in rural areas. The loss of metal that will occur in bare steel will be about 50 $\mu m$ (0.002 in) in a rural area but may double near an industrial complex.

Inside a building, the conditions will depend upon factors such as the form of construction, the use to which it is put and the amount of ventilation.

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Relative humidity has an important influence on corrosion and if maintained below about 70 per cent, corrosion will be negligible.

Acidic conditions will tend to cause severe corrosion of steel. For example lactic acid can result in the loss of more than 1.25 mm (0.050 in) of steel per year. Some constituents of fertilisers may also be very corrosive.

A particularly severe situation occurs when corrosive material is placed against steel so that it is in permanent contact with it. This often occurs at ground level and particular attention should be paid to such situations. This will be considered in more detail later when discussing preventive measures.

Agricultural equipment can suffer from corrosion in the same way as do buildings. In many situations corrosion-resistant steels can be used eg for dairy equipment. The major problems arise in equipment and machines that may be used for comparatively short periods and are then stored unprotected for longer periods.

Absorbent material should not be placed in direct contact with steel. Steel may corrode at an accelerated rate if in contact with wood, certain types of plaster and hardboard, in situations where they are wet.

## Prevention of corrosion

**(a) Buildings**

Two different types of steel product are incorporated into buildings –

(i) cladding and

(ii) structural members in frames.

As the pre-coated strip is produced under factory conditions it will generally prove far more durable than site-applied coatings. However, there are situations where bare galvanised sheet is used or where the building is painted after erection. In many cases, galvanised steel will provide long-term protection without additional coatings. But its 'life' will depend on the environment of exposure and the thickness of the coating; there is a virtually linear relationship between thickness and life to failure.

In conditions where galvanised sheet is not suitable it may be necessary to apply coatings. Problems have arisen with adhesion of the paint to freshly galvanised surfaces and certain treatments are recommended to avoid these difficulties.

Generally, the cladding is exposed to less severe conditions on the insides of buildings. However, the reverse is true in specialised buildings such as silos. Galvanised coatings alone are not generally suitable for such conditions. Vitreous enamel, although expensive is very resistant but more often chemical-resistant coatings such as coal-tar epoxide are applied to galvanised steel.

Structural members cannot generally be galvanised or coated with paints or plastics in a continuous process. Consequently the coating processes must be carried out separately, so sections are generally protected by paints.

There is a wide variety of paint coatings that can be applied to steel sections. Generally for external and internal use, oleo-resinous paints are satisfactory but for more severe conditions thicker chemical-resistant paints must be used. The cheapest of these are the bituminous compositions which, provided they are of the high-build type, will be quite satisfactory for many internal situations.

Weathering steels are a comparatively recent development and designers should obtain advice from BSC before specifying them. Although they have not yet been used to any extent in agricultural buildings, these steels, the best known of which is Cor-Ten, could in many circumstances prove to be the most economic way of controlling corrosion.

**(b) Equipment and machinery**

Stainless steels are widely used for dairy and processing equipment and generally corrosion is a very minor problem.

Problems may arise on mobile machinery and equipment used on farms. Generally, by the nature of farm work, plant tends to be stored for long periods. During storage corrosion may be more severe than during use, so equipment should be cleaned and coated with grease.

## Design

In animal buildings, the most aggressive situations are often at ground level and special precautions should be taken in these areas. The effects of condensation have already been noted. Apart from the attack on the steel or galvanised coatings, moisture tends to run down the inside walls of the building causing corrosion at places that may be hidden from view. Crevices and overlaps are features that can lead to corrosive situations particularly where conditions are acidic or damp. Problems can arise where the design does not allow adequate access for maintenance.

# The chemical resistance to concrete

D E Shirley

CONCRETE is not an invariable homogeneous material. We have control over factors such as the type and quantity of the aggregate to be used, and can thus influence the permeability of the mass to aggressive solutions. On the other hand, we have little choice in the matter of hydraulic binders – if we require a powder which will react with water to form a hardened mass, as cement does, we must expect it to be potentially reactive in other ways which may not be beneficial.

Portland cement may be thought of as consisting essentially of anhydrous calcium silicates which possess the ability to react with water to form a stable mass of crystalline interlocking hydrates. Such silicates do not occur naturally, but must be synthesized.

Whilst each of the resulting cement particles consists predominantly of the desired cementing minerals such as di-calcium silicate and tricalcium silicate, impurities in the raw materials give rise to other constituents. However, the high calcium content of the cementing minerals should be noted. A typical Portland cement has nearly two-thirds of its weight in the form of calcium oxide. In chemical terms it is 'basic' in nature and thus potentially capable of reacting with acids.

When considering the chemical resistance of concrete the possible reactivity of the aggregate has also to be borne in mind. Whilst many rocks such as flint, quartzite and granite can be regarded as inert towards most of the aggressive environments which are commonly met, limestone – calcium carbonate – is readily attacked by acids.

Nevertheless, it must be borne in mind that there are two sides to a chemical reaction, and that in the case of acids the process is sometimes summarised as 'Acid + base = salt and water'. That is to say, a cement paste is capable of acting in the manner previously mentioned in connection with limestone: an acid which attacks it is converted into calcium salt and rendered harmless.

Much depends, however, on the permeability of the cement paste. If the original cement content of the paste were low, the volume of hydration products would be insufficient to form a close-knit structure.

If, on the other hand, the original paste were to have a high cement content, spilt acid would be unable to penetrate rapidly, but would remain in contact only with the basic hydration products on the concrete's surface. Attack and neutralisation would be largely confined to that surface. This principle underlies the use of acid solutions to roughen the surface of good quality concrete floors which have been worn to such a smoothness as to be slippery.

In rare cases, such as that of oxalic acid, the salt formed by reaction between acid and cement paste is insoluble. The initial reaction thus provides a stable protective layer which inhibits further attack – provided, that is, that the layer remains undisturbed.

In most instances, however, a second spillage of acid on an area already attacked merely results in a repetition of the original reaction. The combination of abrasion and acid attack is a particularly destructive one.

Of course, if the supply of such acid in contact with the concrete is constantly renewed, as may be the case in a tank, pit or channel, the steps described merge into a continuous process. A rough working rule states that the rate of chemical reaction doubles for every 10°C rise in temperature. Clearly, therefore, a combination of a warm aggressive solution and abrasion – as often occurs on

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factory floors — constitutes a particularly punishing environment for concrete.

Unfortunately, acids are not the only compounds which will react with the basic components of cement paste. Sugar solutions, animal fats and vegetable oils (but not mineral oils) contain complex organic compounds, which may possess reactive groups capable of combining with the hydration products and converting them from useful crystalline compounds into weak soap-like materials. However these organic compounds generally react much more sluggishly than the acids discussed previously.

The basic nature of cement pastes confers upon concrete a good resistance to alkaline conditions, provided that the alkalinity does not arise from a concentrated solution.

We are left with the conclusions that concrete is by no means to be listed among the 'corrosion-proof' materials, and that no admixture or surface treatment can significantly alter the chemically basic nature of cements. Provided this vulnerability is recognised, however, and concrete is not expected to withstand indefinite exposure to powerfully aggressive conditions, we find that it is able to shrug off occasional corrosive spillage with no more than a change of surface appearance. It can even serve as a low-cost expendable container in some circumstances.

However, its ability to fulfil these functions depends upon the action of the attacking agent being confined to the exposed surface. This implies a thoroughly compacted concrete, in which all interstices between aggregate grains are filled with a cement paste having a high solids content and a low void content. Pastes of this type are only obtained at water/cement ratios below 0.5, and to achieve adequately workable concretes at water/cement ratios of this order requires generous cement contents. Typically, if a 20 mm aggregate is used, about one part by weight of cement to 4½ parts of aggregate will be needed (or 400 kg of cement per cubic metre of concrete) to produce a concrete of the quality envisaged.

# Corrosion in field machinery— a manufacturer's view

R S Sargent

IT is the role of the manufacturer to make full use of materials on the market and with a thorough knowledge of what causes corrosion and where it most affects the efficiency of the machine, to use the exotic materials in small economical quantities to their best advantage so as to be able to offer his machinery at a price the farmer will pay.

All types of farm machinery suffer from corrosive attack in one way or another, be it only from the natural elements, but principally the machines most affected by corrosion are those directly concerned with the handling or distribution of fertilisers.

With regard to the former, there is little the manufacturer can do except to ensure that the machine arrives on the farm in good condition and advise on how best to care for it after use; from then on it is up to the user to exercise care when storing out of season.

There are two main methods of preventing or combating, at the manufacturing stage, corrosion by fertilizers.

1. By covering the metal with a protective coating such as paint.
2. By replacing the metal by some substance which is not corroded under operating conditions, ie a more resistant but more expensive metal such as stainless steel, or a plastic which has the required properties, but, although cheap in its own right, may require expensive development and moulding tools.

## Paint finish

Paint, if properly applied, will give good protection for the structural parts of the machine but cannot be used on working parts.

If the paint is to be durable, it must be of good quality and the preparation of the part carefully carried out. Because deliveries of steel cannot always be stored immediately or in ideal conditions, it is usually necessary and certainly advisable to include pickling as part of the pre-treatment.

*R S Sargent is of Massey-Ferguson, Coventry.*

**Typical paint pre-treatment involves**

1. Pickling in warm/hot dilute sulphuric acid solution to remove millscale, grease and rust.
2. "Phosphating" with iron phosphate to provide good key and resist corrosion.
3. Washing in hot water and force dry.
4. Sealing with proprietary phosphate seal such as a chromate rinse to prevent deterioration of phosphate.
5. Priming with zinc chromate primer by spray or dip and
   a. air drying
   b. force drying in oven at 180°F, or,
   c. full baking in oven at 250°–300° for half an hour.

## Resistant materials

A 15-row combined seed and fertiliser drill would retail at around £4000 if made in stainless steel or approximately 2¼ times one made in mild steel with some resistant materials included. This would, of course, be wasteful, totally unnecessary and unsaleable.

The advancing technology of the plastics industry opens a very wide door to the manufacturer in the battle against corrosion, but it is the skill of the designer in selecting the correct material and the correct application for the use of the plastics where their use pays off.

Wood is a material which is resistant to corrosion and with care will last many years. It still has its place in agricultural machinery notably in plywood form for trailers and manure spreader floors, slurry gates, bearings, chain tensioners and the like.

Where it is impossible to use corrosion resistant materials, or where painting or plating is not likely to last any length of time as on manure spreader bed chains then the only option is to accept the fact and make them dimensionally sufficient so that the corrosion has relatively little effect and reasonable service life is achieved.

# Corrosion prevention in agriculture with petroleum based protectives

E F Sudron

THIS paper discusses temporary corrosion protection as is required for agricultural machinery. This includes a wide variety of equipment for which the period of protection may range from less than a month to several months in a year.

Metal surfaces can be protected against corrosion by preventing moist air from coming into contact with them. A convenient and effective way of doing this is to apply an impervious coating to the metal. If this protection is to be temporary it is important that the protectives should be easy to apply and, when protection is no longer needed, easy to remove. In some instances removal may be unnecessary and, when this is so, the nature of the film must be such that it will not be objectionable when the article is in use or during subsequent working operations.

The varied nature of the work for which this kind of protection is required demands a full range of products so as to provide for the individual needs of each particular job. Modern petroleum-based protectives meet these requirements in full.

## Temporary corrosion preventives

Temporary corrosion preventives are products designed for the short-term protection of metal surfaces.

The major categories of temporary corrosion preventives are:

1. Soft-film protectives:
   a. dewatering fluids giving soft/medium films,

*E F Sudron is of Shell Marketing Ltd, London.*

b. non-dewatering fluids giving soft/medium films,
c. greases.
2. Hard-film protectives.
3. Oil protectives:
a. general purpose,
b. engine protectives.

The protectives are easily removable, if necessary, by wiping or with petroleum solvents. Some products for use in internal machine parts are miscible and compatible with the ultimate permanent lubricant, and do not therefore need to be removed.

1. Soft-film protectives: A thin, soft protective film can be applied to a component by a liquid consisting basically of two parts: the film-forming material and a carrier. The carrier is a solvent that evaporates after application, leaving the protective film evenly distributed.

Where the surfaces to be protected are wet, the protective solution can be given dewatering properties by the incorporation of additives.

Where a thick soft protective film is required a grease may be used.

2. Hard-film protectives: Automobile under-body sealing is an example of the use of a hard-film protective. A tough, resilient film is left when the solvent 'carrier' has evaporated. Depending on the amount of wear to which it is subjected, these products give a much longer term of protection than do the soft-film materials.

3. Oil protectives: These materials are lubricating oils containing corrosion inhibitors and are mainly for use on internal surfaces such as in internal-combustion engines and gear boxes. They may be applied to small parts such as washers and screws, for which protectives containing solvents are impracticable.

## Selection of a corrosion preventive

Temporary corrosion preventives are in some cases required to give protection against rusting for periods of only a few days for inter-process waiting in factories. Where the protected components are not exposed to the weather, protection can be given of up to a year or more for stored components in internal storage conditions. On the other hand, components may require protection for a few days or even weeks under the most adverse weather conditions. Some components may have to be handled frequently during transit or storage. In general, therefore, the more adverse the conditions of storage, the longer the protection periods and the more frequent the handling, the thicker or more durable the protective film must be.

For good results the metal surfaces should be reasonably clean before the protective is applied. If complete protection is essential, the surfaces must be very clean. Practically all kinds of foreign material, including those of an oily or greasy nature, are capble of obstructing the action of the protective.

Petroleum-base protectives are, in general, inflammable and precautions against fire must be taken in using them.

Precautions should also be taken to ensure that certain protectives do not come into contact with components made of natural rubber or plastics that are adversely affected by petroleum-based protectives.

All unpainted internal surfaces, including those which in service come into contact with lubricating oil, require protection after the lubricant has been taken out of service.

Surfaces or parts forming a lubricating oil system can normally be cleaned effectively by using a flushing oil. This should be done before the protective is applied.

## Methods of application

The most common modes of application are dipping, spraying, brushing or swabbing. These methods are suitable for solvent-based protectives, soft-film and hard film fluids and for dewatering fluids. Spraying should be uniform to form an even coating: brushing or swabbing should merely lay the fluid onto the metal surface, rather than work it in as in painting.

All solvent-based fluids when applied require precautions against fire risk.

All types of petroleum-base protective films may be removed with petroleum solvents, such as white spirit is recommended. Petroleum solvent cleaning can be used for any metal surfaces with a high finish. Care must be made with solvent cleaning where the solvent might come into contact with organic materials such as fabric or rubber.

## Conclusion

Corrosion protection of agricultural machinery, particularly that which has a seasonal work pattern, is very important, to ensure that it is maintained in a serviceable condition. Considerable scope exists for the use of petroleum-based protectives to minimise corrosion problems.

It is important to remember the high costs of corrosion: shorter machine life, more expensive maintenance costs, and increased down-time of machinery at what may be a crucial period. To put the cost of corrosion control into perspective, the cost of materials required to protect a machine of high capital cost, eg a combine harvester, will only be in the region of £10.00, a tiny amount when compared with the cost of the machine itself.

# Health and safety

SINCE the Health and Safety at Work, etc, Act was introduced in April 1974, industry has given increasing attention to the protection of people at work from hazards to health and safety. In agriculture, problems have arisen at Government level concerning responsibility for safety. Systems of work and the wide range of machinery and equipment used, often in difficult environmental conditions, contribute particularly to health and safety problems in agriculture. The farmer and those serving the agricultural industry are required by the Act to face these problems and minimise their adverse effects on the operator. The agricultural engineer has an important role to play in this work. The Editorial Panel consider that it would be helpful to acquaint members of the Institution with developments in health and safety by presenting a regular feature in the Journal, based on official communications received by the Secretariat. Other news and views on the subject would be welcomed and members are invited to write to the Secretary if they have material which may be included in future reports.

Communications received from the Health and Safety Commission draw attention to a booklet which is now available through HMSO on legislation proposals for safety representatives and committees. The Government has decided not to implement these proposals for the time being on grounds of potential cost in the public sector. The Commission is concerned about this delay and in a letter sent to the Secretary of State for Employment in December 1976 suggests that the credibility of the Commission will be undermined if the regulations are not laid before Parliament without delay.

The Commission announced the names of twelve members of the Agriculture Industry Advisory Committee in December 1976. The committee will advise the Commission on matters relating to health and safety in agriculture, including horticulture and forestry which arise in England, Wales and Scotland. Six members of the committee have been nominated by the CBI and six by the TUC. The committee will be chaired by John Weeks, Fellow and President-elect of the Institution, who is now head of the Agricultural Branch of the Health and Safety Executive.

The Executive assumed responsibility for agricultural health and safety matters in Great Britain on 1 March 1976. Its first exhibit at the Royal Smithfield Show gave prominence to tractor safety cabs and included an approved 'Q' cab, complete with hazard warning lights. Literature is available from the Executive on the 'quiet' cab concept, together with up-to-date details of approved safety cabs and frames for pre-1970 tractors, which must have safety cabs fitted by September 1st 1977. A pamphlet explaining the implications for agriculture of the Health and Safety at Work Act 1974 is also available.

From September 1970 the Agriculture (Tractor Cabs) Regulations have required new tractors to be fitted with approved safety cabs which must now be 'quiet', ensuring that noise at the driver's ear does not exceed 90 dB(A). From 1 September 1977 all new cabs are required to be 'Q' cabs.

*BAM*

# Corrosion: A farmer's view

J. Smart.

WE have always had to admit, or accept, that no farmer ever has sufficient building cover for his equipment, and some of our critics might say that even if he has enough he does not always use it. So much of our cultivation equipment with few, or no, moving parts such as rolls, cultivators and harrows, or even ploughs, are normally stored in the open which certainly does not help with the problem of corrosion but with the exception of plough mould boards, the effects of corrosion are not so damaging provided that any moving parts, are kept well oiled. The wearing parts on this type of cultivation equipment such as cultivator points, harrow tines or ploughshares are regarded as expendable, or at least replaceable, and the effect of corrosion is minimal compared with the wear which takes place as the implement moves through the soil.

So seen in perspective, corrosion is less of a problem in the old blacksmith-made type of equipment than it is in the more sophisticated and complicated machine – and here it must be said that many machines are becoming plenty complicated enough for the conditions under which they are expected to operate. To my mind there is no point in putting, say, an X-ray sorter on a potato-harvester. If you must have this piece of equipment it should be at the store where at least it can work in comparative comfort.

The machines which are most vulnerable to the effects of corrosion are those designed to handle chemicals – mostly artificial fertiliser, either in solid or liquid form, but also some spray chemicals. Corrosion in these machines could cause seizing-up of moving parts, distortion of metering equipment, or blocking up of outlets all leading to damage to the machine or at least uneven distribution and it is in these machines that the use of non-corrosive materials is most justified even if the parts concerned have only a short life, so long as they are replaceable.

One of the major problems facing the farmer today is to decide how long he should expect, or require, a piece of equipment or machinery to last and how often he should plan to replace it. Planned obsolescence, which one feels must be part of the philosophy of many manufacturers these days, is not something we want to see in agriculture, but many machines are still being developed or improved so unless they are renewed at reasonably frequent intervals they can soon become out of date. So it is really a question of striking a sensible balance and if the cost of non-corrosive materials is too much in excess of that of the normal corrosion susceptible ones then it is probably not justifiable to plan for the longer life at the higher cost. Much more important is that machinery should be free from corrosion which would result in breakdowns and loss of working time. For time appears to be the commodity in shortest supply.

With buildings the farmer faces the same problems as other users, and these problems can be accentuated by the uses to which the buildings are put. Protective coatings have their uses but nearly all have the problem of wear or chipping, and these days we tend to use asbestos sheeting for roof-cladding and often concrete for the structural part of the building as being at least less liable to corrosion than steel.

The attitude of the farmer towards the problem of corrosion might be summarised as follows:–

1) The most important effect of corrosion is that in machinery which causes stoppages, breakdowns or poor performance.
2) This could be minimised if we could afford to have adequate dry and well ventilated cover for all our equipment.
3) The corrosion of the less complicated field equipment is comparatively unimportant compared with the wear which takes place during use.
4) Corrosion can be minimised by applying a protective coating of oil or grease when equipment is not in use. Occasionally also the farmer may find the time to repaint some of his machinery.
5) The choice between non-corrosive materials and protective coatings must ultimately depend on relative costs. Thus in the dairy we can afford to use stainless steel, in buildings we can use asbestos but for most of our field equipment steel is still the only practical material and this has to be protected in the best way possible.

*J Smart is from Nocton Farms Ltd, Lincoln.*

## Edited summary of discussion

**Dr Elliott** (UMIST), commenting on Dr Bowden's paper, reported that subjective estimates by farmers, of corrosion problems which they had experienced, pointed towards the occurrence of greatest problems in fertiliser distributors, tractors, and in stock buildings. Combine harvesters and silage stores featured much less prominently in their estimates.

**Dr M Moore** (NIAE), saw the combined effects of corrosion and wear as a major problem. It was also apparent that increased corrosion occurred from the presence of copper in pig slurry. Dr Bowden observed that American research supported Dr Moore's observation regarding wear and corrosion. He quoted the silage unloader where periods of work were followed by periods of rest during which corrosion could well set in. More investigation was required.

**Dr J Johnson** (UMIST), asked Mr Randall about the relative corrosivity of the various slurries. What caused the difference? Mr Randall observed that pig slurry did not often cause problems, whereas pig and cattle slurry together had proved corrosive. Pig and hen slurry was worse in this direction than cattle slurry. He felt that the difference arose largely because of differences in solid content and viscosity of the slurries in question. Cattle slurry tended to cake and form a protective coat. Dr Moore observed that the copper present in pig slurry may cause trouble in aluminium pipes.

**Mr P Friend** (MAFF), requested information on the formation of "white rust" on galvanised steel sheets. Many cases were being reported. Mr Turner observed that the causes of white rust had been known for some years. The problem occurred largely when a static layer of moisture was allowed to form on the sheets. Mr Layton observed that the trouble often occurred under bad storage conditions; in this respect corrosion was a management problem.

**Dr J Wilcock** (Zinc Development Association), stated that white rust – a zinc carbonate deposit – was not a problem in itself. If quickly removed it did not significantly damage the galvanised coating. Any damage could be repaired by zinc rich paint. Most trouble occurred if the carbonate was not removed and atmospheric pollutants were absorbed. Potential damage was then great and the thickness of the remaining protection should then be checked with an appropriate gauge.

**Mr C Brutey** (NFU), asked if on site use of blast cleaning of steel were practical prior to painting. Mr Chandler replied that this was possible but it was easier if this was performed by fabricators or at the mill. He referred to the Health and Safety at Work Act, saying that abrasive must be kept well clear of adjoining structures or equipment to ensure that no damage to them occurred.

**Mr C J Kettel** (Forward Lubricants Limited), enquired of Mr Shirley what was the effect of an inclusion of calcium chloride into concrete which was used in proximity to steel work? Mr Shirley observed that calcium chloride was an effective and cheap accelerator in the hardening of concrete. Unfortunately it reduced the protection that the concrete offered to reinforcement. There were no major problems in plain concrete, but the accelerator should not be employed in reinforced or pre-stressed installations. Early warning of corrosion damage was given by the appearance of a brown stain followed ultimately by the bursting of the concrete along reinforcement lines. He warned against the use of any "magic" accelerator in adverse weather conditions.

**Dr Moore** enquired of the speakers as to the direction in which corrosion protection in agriculture ought to develop during the next ten years. Mr Berry saw the need for work on an additive which would enable corrosion to be reduced. Mr Randall saw the need for a cost effectiveness balance to be struck – what was the farmer prepared to pay for? Mr Turner observed that innovations were expensive and many of these ultimately proved unsuccessful. He favoured the review of some well established techniques which might well be re-employed. Mr Sergeant looked to further investigation in the field of plastics and in this he was supported by Mr Smart who made a plea for a drive towards a reduction in the number of breakdowns in equipment. Mr Sudron felt that present research would stand us in good stead for some time. There was need now for the development and use of our existing knowledge. Mr Chandler agreed that there must be greater contact between the specialist and the user and in this he was supported by Dr Bowden.

In summing up, the Chairman drew attention to this general agreement among the speakers that corrosion control both in industry and agriculture was often a case of using existing knowledge. Indeed this was the reason for the Conference having been mounted jointly by the Department of Trade and Industry and the Institution of Agricultural Engineers.

# Around the branches

## London/Kent Branch inauguration

THE President and President-Elect, together with Professor B A May and the Institution Secretary, attended the inaugural meeting of the London/Kent Branch held at the Farmers' Club, London, on Thursday 16 December 1976.

The President, in officially announcing the formation of the Branch, said that it could play an important and unique part in the future activities of the Institution, firstly, in a "hosting role" to overseas and expatriate members visiting London; secondly, in a liaison capacity in particular with government offices; and thirdly, establishing closer links with representatives of overseas governments, and with multi-national companies engaged in agricultural engineering and allied activities.

Officers elected were:-

K D Seiler (chairman)
E F Sudron (vice-chairman and honorary treasurer)
H G Stirling (honorary secretary)

Messrs I B Warboys, C V Brutey, D H Mingo, J K Wilken and P I Ross were elected as ordinary members of the Branch Committee.

Special thanks were extended to the three chief officers of the new Branch who had done so much towards its formation. Following the formal meeting the members present sat down to an excellent supper.

A paper was then presented by Professor B A May (Head of the National College of Agricultural Engineering) — The Role of the Academic in Industry. He first spoke of the reasons for the "lofty indifference" which so often exists in the relationship between industry and the academic world. The academic is accused of insensitivity to deadlines, of vulnerability to distraction from the objective of a project, of unwillingness to accept work under a closely specified contract and of ignorance of the human and environmental implications of technology. Industry, on the other hand, is said to be bereft of the imagination to see long-term potential, to be unreliable in meeting obligations, uninterested in sponsored research and to misuse and misunderstand the facilities and requirements of universities.

The approach of the Cranfield Institute of Technology (CIT), to meeting this problem of inter-relationship was described. In particular the National College of Agricultural Engineering, which now forms a Faculty of CIT concerned with agricultural engineering, food production and land resources, is making special efforts to improve its contacts with industry. The College recognises that the quality and relevance of its work to industrial needs will largely influence the extent to which effective links can be made.

The audience was reminded of the professional and industrial liaison committee, formed early in 1976, to promote interchange between NCAE and the agricultural engineering industry.

## Northern

THE speaker at the meeting on 5 October 1976 of Northern Branch IAgrE, held in the Agricultural Engineering Department of the Edinburgh School of Agriculture, was Dr A D Trapp who spoke on *Climatic control in livestock housing.*

Dr Trapp opened his talk by stressing the need to design intensive livestock houses to suit the climatic requirements of the stock. A chart showing approximate lower critical temperature ranges led to the conclusion that while cattle and calves could survive well at all temperatures likely to occur in the British Isles, it was necessary to pay attention to the detail design of the buildings. In particular, it must be ensured that calves were not subjected to cold draughts or wet bedding. The main problem encountered in these buildings was inadequate ventilation; an approximate formula for calculating the area of an open ridge to provide the required ventilation rate by stack effect was given. A diagram of the SFBIU climatic calf house was used to illustrate some essential design features of this type of housing. It was concluded that for cattle and calves it was not necessary to have insulated structures, forced ventilation (except in difficult conversions), or artificial heating. In fact, for cattle it was even possible to eliminate the roof although there were problems of muck disposal.

Referring to pigs and poultry, the speaker used a conceptual model demonstrating the relationship between feed intake, heat loss and energy available for conversion into useful product. He briefly described the history of thermoregulation research indicating that the major effort had necessarily gone into basic research. However it was now appropriate to put more effort into usefully applying the results of this research to real farming situations. Dr Trapp said that some classes of pig needed temperatures up to 30°C above the coldest outside temperatures that occurred. To explain the thermodynamics of pig housing a simple heat balance was used. The required heat and moisture production data were shown, based on information provided by the ARC Institute of Animal Physiology at Babraham. The heat loss due to conduction through the fabric of an existing growing/finishing house amounted to 0.94 W/°C pig which for an outside temperature of 0°C and a house temperature of 15°C gave a conduction heat loss of 14 W per pig. The total heat production from the average 57 kg pig was 150 W and thus the conduction loss accounted for only 9% of this heat production. Neglecting radiation losses, the remaining 91% of heat production was lost through the ventilation system. Latent heat accounted for 20% of total heat production producing a moisture output of 44 g/h pig. Dr Trapp stated that heat and moisture production from pigs normally determined the ventilation rate requirements in pig housing and, provided that these factors were dealt with, problems due to dust build up and noxious gases were minimal. Assuming an absolute minimum ventilation rate of 0.2 $m^3$/h kg liveweight, it was shown that for a house temperature of 15°C and an outside temperature of −6°C there was still an excess of heat available from the pig and thus the ventilation rate would need to exceed 0.2 $m^3$/h kg liveweight even under these extreme conditions. It was also shown that for a ventilation rate range of 0.2 to 1.5 $m^3$/h kg liveweight, the effect on house temperature of doubling the ventilation rate throughout the range was small at the maximum rates of ventilation, but was very significant at low ventilation rates corresponding to cold weather conditions. The conclusion was that to double the maximum capacity of a ventilation system would provide little benefit but there was considerable advantage in providing close control over low rates of ventilation.

The speaker suggested that a maximum to minimum ventilation rate ratio of 10:1 might be appropriate for many pig housing situations although ratios as high as 50:1 could be desirable in early weaning systems. The ideal ventilation system would provide accurate control of low ventilation rates together with good distribution of fresh air with cold air not directed onto the pigs. At maximum rates of ventilation, air movement should be high close to the pigs.

Dr Trapp went on to describe two practical systems of ventilation control designed to minimise the problems which arise from the wind vulnerability, or even the influence of stack effect on slow running fans. In the first system a motorised flap was used to allow air from within the house to mix with fresh air thus allowing the fan to run at a reasonable speed while controlling the rate of incoming fresh air. This system, developed by Owen, used perforated polythene ducts for air distribution and the high rates of airflow through the fan enabled good distribution of air to be maintained even in the coldest weather. The second control system described by the speaker, allowed four rates of ventilation; the lowest rate operating continuously and the other three being progressively switched in by three thermostats as the house temperature rose. The four rates corresponded to 0.18, 0.35, 0.70 and 1.51 $m^3$/h kg liveweight, for the growing/finishing house.

## South East Midlands

A FORUM, dealing with the present and future uses of straw, was very well attended by members and visitors from far afield. The meeting was held on 22 November at NCAE, Silsoe and addressed by four speakers who are actively investigating various aspects of the handling and utilisation of this controversial "bi-product". During the four hour proceedings, ample opportunity was given for general discussion — opportunity which was eagerly taken up by the audience.

In the opening paper, Dr R W Radley, of NCAE, presented a review of the production statistics of straw and the present day fate of the material. He also summarised the economic aspects of straw "procurement" from farm to factory.

The development of cereal acreage over the past fifteen years was discussed and the speaker felt it likely that the area occupied by cereals would be increased to four million hectares over the next decade: also that the proportion devoted to wheat would increase. The yields of straw from the various cereal crops were mentioned but the speaker commented on the difficulty of collecting straw yield information and made a plea to those engaged in the compilation of agricultural statistics to pay more attention to this commodity.

The costs of baling, handling and transporting straw (over various distances) using various types of baler and handling systems was shown alongside cost data for new systems currently being developed.

Mr W Klinner of NIAE, spoke on the matter of densification. He referred to the effectiveness of evacuation as a principle for increasing the density of straw packages and compared this with mechanical compression. Results of field experiments on evacuation suggested that densities of 130 kg/m$^3$ were realistic whereas with mechanical compression a density increase of only about 40% was likely with techniques which had been investigated.

Mr H Jones of BOCM Silcock Limited, considered straw from the processors' point of view. He showed a film which featured the BOCM process for treating straw with sodium hydroxide. The material was chopped in a tub grinder, mixed, pelleted and allowed to rest for a short period, and was then available for dispatch. The nutritional value of straw was increased by this treatment from 5.8 MJ/kg to 8.9 MJ/kg. Diets containing up to 60% treated straw had been fed — initially a problem of palatability was encountered, but animals "acclimatised".

Mr B Wilton, of the University of Nottingham was concerned with the calorific value of straw when considered as a fuel. Wheat straw had a value of 19.8 MJ/kg compared with 42 MJ/kg for oil. The financial value of straw thus appeared to be about £20.00 per tonne. When burned, straw produced an innocuous white ash: its low sulphur content was also noticeable. The speaker referred to equipment which had been designed in Germany for drying poultry manure: large bales were used here as the fuel and were mechanically handled into the combustion chamber in a semi-continuous fashion. Work at the University of Nottingham was proceeding in the development of a suitable combustion chamber for chopped straw which was available from a whole crop harvesting programme. Currently, combustion had been achieved which produced clean output gas at about 600°C, the efficiency of combustion being approximately 73%. The generated heat was to be used for drying barley which was intended for stock feed and a block diagram of the equipment was shown to the audience.

## West Midlands

THE *Treatment and utilisation of farm animal wastes* was the subject of a talk given to West Midlands Branch IAgrE, on 29 November 1976, by Dr S Baines, of the West of Scotland Agricultural College.

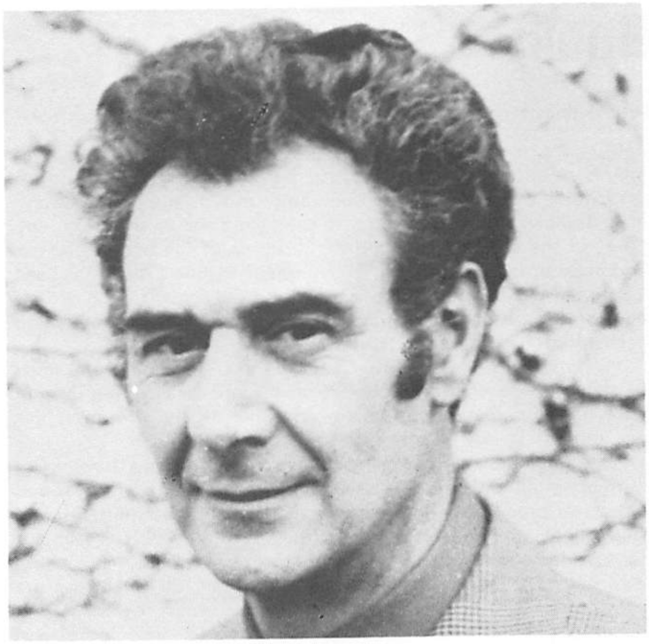
Animal excreta had been traditionally returned to land either during grazing or as farm yard manure. However, its return as a semi-liquid slurry especially from intensively housed pigs and poultry had given rise to problems of water pollution, odour and increased risk of dissemination of pathogens. Treatment of slurry was therefore aimed at reducing these problems and promoting ease of handling, said Dr Baines.

It was desirable that the extra cost of food production related to environmental control be recovered by the utilisation or recycling of slurry components as fertiliser, fuel or animal feed.

The recovery and utilisation of crop nutrients in slurry entailed long term storage so that the time of application coincided with crop uptake and with moisture deficiency in soils. Stocking densities were also limited by the nutrient requirements of grass for grazing or conservation or of other crops. Stocking density of pigs and poultry was limited by nitrogen, whereas that of cattle was limited by potassium to avoid problems of hypermagnesia. A further limitation was that of hydraulic loading to prevent surface run-off and maintain moisture deficiency, thereby avoiding water pollution through drainage systems.

Whereas these practises would virtually eliminate risks of surface and ground water pollution, odour may be accentuated due to the solubilisation of organic compounds during anaerobic storage. Pathogenic micro-organisms had been shown to survive in stored slurry and therefore, their dissemination might be more widespread because of the increased requirement for land. Present methods of spreading slurry produced aerosols and increased both the odour problem and the risk of disease.

The controlled aerobic and/or anaerobic treatmént of organic wastes were methods of selection and concentration of the natural microbiological processes which occurred in soils and water. They were continuous mixed cultures of micro-organisms utilising components of a complex substrate and producing a variety of end products dependent on operating conditions. Such treatment systems could be designed to prevent odour, reduce the risk of



*Dr S Barnes*

pathogen dispersal and reduce the requirement for land where desirable.

Aerobic treatment had been extensively studied at the West of Scotland Agricultural College. Laboratory-scale experiments showed the effect of substrate loading, dissolved oxygen concentration and temperature on the end products and particularly on nitrogen transformations. The results provided models for commercial scale treatment systems to meet one or more of the desired objectives.

Anaerobic digestion of slurries under controlled conditions permitted a methane fermentation along with a reduction in solids and pollution potential. Additional aerobic treatment might be required prior to land application.

The treatment of organic wastes in microbiological systems gave rise to growth of micro-organisms. These microbial sludges were a form of single cell protein. Optimising sludge production required an increase in the available carbon in the slurry. The resulting material was variable, might contain pathogens and the value of such a process was therefore questionable.

More sophisticated techniques of utilising some of the slurry components of slurry as substrates for SCP of greater value were being evaluated. Species of yeasts could be grown on hydrolysed slurry, utilising pentose sugars released from hemicellulose and other yeasts would grow on volatile fatty acids formed during anaerobic storage of slurry. Complex biological systems involving anaerobic digestion, aerobic treatment and algal culture to remove inorganic nutrients gave rise to methane, bacterial sludges and algae as potential animal feeds supplements and clean water.

The economic viability of all these processes in food production would depend on the costs of alternative sources of fertiliser, fuel and animal feeds and also on pressures by government and society to further improve the quality of the environment.

## Yorkshire

AN extremely interesting and worthwhile visit was made to the York sugar beet factory on Thursday 18 November by members of the Yorkshire Branch IAgrE. A short film introduced the party to the processes involved, and so interesting was the tour that it took over two hours to arrive back at the starting point. Members were particularly impressed by the high degree of automation at this recently modernised and enlarged factory and by the eagerness of employees at all levels to explain with obvious pride their particular responsibilities in the process.

# Books

## Farm machinery

SINCE Claude Culpin's first edition of *Farm Machinery* was published in 1938, technological development in the field of agricultural engineering has been rapid and diverse. It is always difficult, in a changing climate, to produce a standard text on any aspect of the subject and avoid the dilemma of the book being out of date almost as soon as it is published. Claude Culpin has been undaunted by this prospect and has served the agricultural engineering profession well with his prolific writing on farm machinery and mechanisation management.

His latest book is the 9th edition of *Farm Machinery* and must rank among one of the best books on the subject covering the full range of machinery, equipment and the supply of power for agriculture.

The book has many excellent illustrations and line drawings of up-to-the-minute developments of both machines and mechanised systems of crop and animal production. These add both interest and enlightment to the very comprehensive text. The text is laid out clearly and logically making information retrieval easy. For those who find the change to metrication difficult, all quantities are defined in both imperial and metric units throughout the book, with the exception of heat units; these prove particularly clumsy and laborious to give in both ways so they are expressed only in metric units.

In writing a book covering such a wide range of topics the author has kept to the important facts and the reader is given the opportunity to widen his knowledge by a careful selection of relevant and important references. There is an emphasis on principles which are of basic importance and lasting value rather than upon particular machines which are transitory and soon out-dated by new product developments.

This book makes a significant contribution to the limited number of up-to-date text books on the subject of farm machinery and will be an asset to farmers, agricultural engineers and students of agriculture and farm mechanisation alike.

*Farm Machinery by Claude Culpin. Crosby Lockwood Staples £9.00.*

*IDG*

## Farm buildings and equipment directory

THIS classified directory to the farm buildings industry contains reference to 900 manufacturers and to over 3000 products. Coverage ranges from simple frame structures to package deal, controlled environment houses: from specialist floor finishes to mechanical equipment.

A page of "addresses of useful organisations" mentions relevant research, advisory and educational institutions in addition to a number of professional bodies. The omission of the Institution of Agricultural Engineers from this list will be corrected in the next issue.

*Published by the Farm Buildings Information Centre, £3.00 plus 25p postage.*

*BCS*

## Calf housing handbook

THIS handbook presents information required for the housing of calves up to about 12 weeks of age, and has been written for those concerned with the rearing of beef and dairy calves, no special emphasis being given to veal production. The first chapter covers aspects of behaviour, health and nutrition needed for a good understanding of calf well-being. This is followed by a section discussing the environmental needs of the animals in greater detail, the information being based on recent work done both in the United Kingdom and overseas. Data are given on spatial and lighting requirements in addition to the necessary temperature, humidity and ventilation conditions.

It is pleasing to see a book in which a good balance is struck between design for the animal and design for the operator. The chapter on management activities pays particular attention to the working environment for the stockman and combines this with the operations required for the management of the calves. A section on housing systems and building structure discusses the question of choice of climatic or controlled-environment housing, of feeding systems, and whether or not to consider new buildings or conversion of existing structures. Information is also given on constructional aspects, including design faults and solutions. Layout planning is again treated from both the stock and stockman's points of view, and covers site choice, penning systems and feeding layouts. The final chapter on The Overall Design includes a number of typical examples of calf houses.

A novel system of cross referencing is used within the text, and it is to be hoped that the SFBIU will continue to produce handbooks of this type and standard for other types of livestock housing.

*MPD*

*Calf Housing Handbook, by Dan Mitchell. Published by the Scottish Farm Buildings Investigation Unit, paper back £2.00, hard bound £3.00.*

## New abstracting service

THOSE who still regret the demise of the Agricultural and Horticultural Engineering Abstracts will be pleased to know of two recent additions by the Commonwealth Agricultural Bureaux, to its range of sets of abstracts.

They are: *Agricultural Engineering Abstracts*, (published monthly) and *Irrigation and Drainage Abstracts* (quarterly). The annual subscriptions for these are £35.00 and £20.00 respectively.

The abstracts are available from booksellers or from the Commonwealth Agricultural Bureaux, Farnham Royal, Slough SL2 3BN.

The range of abstracts comprises some 20 titles altogether, including the subjects of animal breeding, dairy science, field crops, forestry, horticulture, soils and fertilisers, and world agricultural economics.

The Bureaux draws its abstracts from about 8000 journals.

# The Douglas Bomford Trust

THE objects of The Douglas Bomford Trust are to assist in education, training and research in the science and practice of agricultural engineering.

The Trustees are empowered to make monetary grants for scholarships, bursaries, prizes and similar purposes in pursuance of these objects.

Applications for awards for the 1977/78 academic year are required by 1 May 1977.

Applications for special projects can be submitted at any time.

Information regarding awards, and the method of applying for same, may be obtained from The Honorary Secretary, The Douglas Bomford Trust, c/o The Institution of Agricultural Engineers, West End Road, Silsoe, Bedford MK45 4DU.

### SEEKING EMPLOYMENT

Members of the Institution seeking new appointments are invited to write to Mrs Ann Stevenson
Institution of Agricultural Engineers, West End Road, Silsoe Bedford MK45 4DU
marking the envelope "Appointments Register" in the top left-hand corner.

# Institution of Agricultural Engineers
# Spring National Conference

(in association with Wrekin Branch)

# Tuesday 29 March 1977

# CROP PROTECTION
# —the facts, the faults, the future

**at Harper Adams Agricultural College, Newport, Salop.**

## Programme

| | |
|---|---|
| 10 15 h | Registration and Coffee. |
| **Morning session** | |
| 10 40 h | Session Chairman – Mr Peter Watson Jones |
| 10 45 h | Paper 1. The Facts – Trends in the development of crop protection chemicals.<br>J G Elliott, Head of Weed Control Department, Agricultural Research Council, Weed Research Organisation, Yarnton, Oxford. |
| 11 05 h | Discussion on Paper 1. |
| 11 25 h | Paper 2. Formulation and the machine.<br>R C Amsden, Head of the Application Equipment Department, Agrochemical Division, Fisons Ltd, Chesterfield Park Research Station, Saffron Walden. |
| 11 45 h | Discussion on Paper 2. |
| 12 05 h | Paper 3. The Faults – The utilisation and performance of field crop sprayers.<br>I R Rutherford, ADAS Liaison Unit, Silsoe. |
| 12 25 h | Discussion on Paper 3. |
| 12 45 h | Lunch. |
| **Afternoon session** | |
| | Session Chairman – Mr Reg Norman. |
| 14 00 h | Paper 4. Application techniques.<br>W D Basford, ADAS Mechanisation Advisory Officer, Nottingham. |
| 14 20 h | Discussion on Paper 4. |
| 14 35 h | Paper 5. The Contractor's view.<br>P J Long, Managing Director, Field Spray Ltd, Colchester |
| 14 55 h | Discussion on Paper 5. |
| 15 10 h | Paper 6. The Future.<br>D A Harris, Manager of the Machinery Development Group, ICI Plant Protection Division, Fernhurst. |
| 15 30 h | Open forum – Conference Chairman and all speakers. |
| 16 15 h | Summing-up and closure by Mr Reg Norman. |
| 16 20 h | Tea. |

**Joint Convenors:**

I D Gedye,
Harper Adams Agricultural College

J Byass,
National Institute of Agricultural Engineering

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