THE AGRICULTURAL ENGINEER

Volume 39, Number 4 WINTER 1984

The Institution of Agricultural Engineers

Journal and Proceedings

THE AGRICULTURAL ENGINEER is published quarterly by the Institution of Agricultural Engineers
West End Road, Silsoe, Bedford MK45 4DU
Tel: 0525 61096

Price £3.50 per copy, annual subscription £14.00 (post free in UK)

Front cover:
Combine harvesting on sloping land
(photograph; SIAE)

THE AGRICULTURAL ENGINEER

Volume 39, Number 4 WINTER 1984

Contents

ISSN 0308-5732

Editorial

The Institution motif

FOR many years now, our Members have proudly accepted the Institution motif embroidered on ties and emblazoned on publications as a means of recognition, as a bond of fellowship and as a symbol of dedication to all matters Agricultural Engineering. The motif was derived from the design of the Presidential Badge of Office but only those who have been privileged to see this Badge at close quarters are aware of the detail of the design which has become blurred and misconstrued in the printed version (fig 1). The quaint "elfin" figure on top of the "unicycle" is *not* Father Time holding a scythe, relevant though it might be; neither is it necessary to sympathise with the maiden clutching an armful of rain blackened crop.

The true symbolism woven into the design was mentioned in the Journal in 1962 when the Presidential Badge of Office was first presented to the Institution by Shell-Mex and BP Ltd to mark the end of a three year term as President of Mr W J Nolan. It was received on behalf of the Institution by the Founder-President, Lt Col Philip Johnson.

The Badge was designed by Mrs

Fig 2 The Presidential Badge of Office

Fig 1 The original motif, L, and the revised version, R

Helen Turner, née Monro, Head of the Department of Glass Design at the Edinburgh College of Art (fig 2). The central figure, engraved on crystal, is Ceres, goddess of the fruits of the earth. The crystal is contained in a silver mount. Above it is a mediaeval sower derived from a figure in the Luttrell Psalter, and below is a gear wheel symbolising the application of power in Agriculture. Regrettably, the design folder has been lost or destroyed since the work was commissioned but the surrounding history and legends forge a powerful bond reaching back to the inception of agriculture in the Ancient World.

The mediaeval sower is abstracted from one of a series of agricultural scenes which appear in the Luttrell Psalter (fig 3). This magnificent text was written and illuminated in the neighbourhood of East Anglia about the year 1340. The borders surrounding each latin psalm are decorated with beautifully coloured cartoons, grotesque monsters (more incredible and extra-terrestrial than any appearing in modern space odysseys) and splendid artwork. The illustration displays a man sowing grain from a rectangular wooden box with wattled sides which he carries slung round his neck. From his right hand a stream of grain is being spread on the seedbed. The operation is somewhat disturbed by the behaviour of two crows, one of which is helping itself from a sack of grain whilst a dog chases the other away. How true to life this is!

The source of inspiration for Ceres has been more difficult to establish, although there is general agreement that the rather coy, peek-a-boo pose is more akin to popular art of the last 50 years or so than to classical iconography, perhaps partly to simplify the engraving processes. It is not surprising, however, that the form of the engraving bears a marked similarity to the pose of the headless figures of Demeter and Kore from the East Pediment of the Parthenon at Athens (fig 4). These statues, now at the British Museum, are part of the Elgin Marbles, casts of which are on permanent display at the Edinburgh College of Art. A better preserved head of the goddess was found at Knidos and is also in the British Museum (fig 5). In contrast with the lack of visual impressions, there are numerous accounts of her exploits in Greek and Roman mythology.

Ceres, the goddess of fruits and riches of the fields, had a temple in Rome but her rites, like the temple itself, were from Greece where Demeter represented the fertile and

Fig 3 The mediaeval sower from the Luttrell Psalter

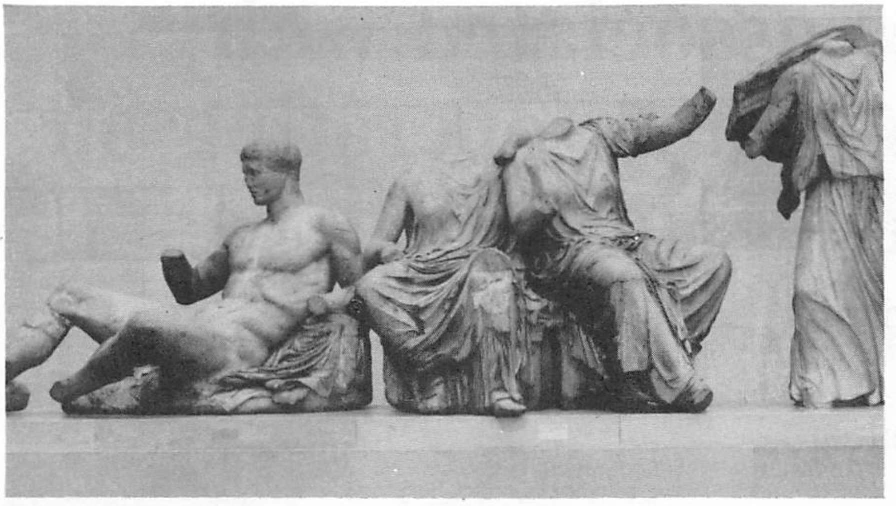


Fig 4 Statues from the East Pediment of the Parthenon: L to R, Dionysus, Demeter, Kore, Iris *(Photograph by courtesy of the British Museum)*

Fig 5 Demeter from a statue at Knidos *(Photograph by courtesy of the British Museum)*

cultivated soil. The name Demeter means 'earth mother'. She presided over the harvest and all the agricultural labours which attend it. As goddess of the earth, Demeter belonged to the group of great Olympians. Her sphere of influence even reached the underworld through her daughter, Kore, who was abducted by Hades. He seized Kore and dragged her down into the depths of the earth, hollowing out a huge cavity in Sicily in the process!

Demeter soon learned that it was Zeus himself who had awarded their child to his brother, Hades. This revelation overwhelmed Demeter. In rage and despair, she withdrew from Olympus. For a long time, she wandered aimlessly in the guise of an old woman. Eventually, she arrived in Eleusis and found refuge in the king's palace there. Later, when her true identity was revealed, a temple was built to her where the initiated should celebrate her mysteries. In gratitude for their hospitality, Demeter gave the king's son the first grain of corn and taught him the art of harnessing oxen to the plough and how to sow the soil with grain. In addition, she gave him a winged chariot harnessed with dragons, and directed him to travel the world, spreading the benefit of agriculture to all men.

Still inconsolable at the loss of her daughter, Demeter returned to the temple of Eleusis. There 'she prepared for mankind a cruel, terrible year: the earth refused to give forth any crop. Then would the entire human race have perished of cruel, biting hunger if Zeus had not been concerned'. After all efforts of conciliation with Demeter had failed, Zeus was forced to give in. He commanded Hades to return young Kore — who since her arrival in the underworld had taken the name Persophone — to her mother. Hades complied with the will of Zeus but, before sending his wife up to the surface of the earth, tempted her to eat a few pomegranate seeds. Now, this fruit was a symbol of marriage and the effect of eating it was to render the union of man and wife indissoluble.

When Kore returned to the world of light, it seemed that Demeter would again lose her daughter because she had tasted the fatal pomegranate. As a compromise, however, Zeus decided that Persophone should live with her husband for one third of the year and pass the other two thirds with her mother. Demeter agreed to set aside her anger and bade the soil again be fertile.

Thus it was explained why each year, when the cold season arrived, that the earth took on an aspect of sadness and mourning: no more verdure, nor flowers in the fields nor leaves on the trees. Hidden in the bowels of the ground, the seeds slept their winter sleep. It was the moment when Persophone went to join her husband among the deep shadows. But, when sweet scented Spring came, the earth put on its mantle of a thousand flowers to greet the return of Kore, who rose in radiance, 'a wondrous sight for gods and men'. These Eleusinian Mysteries are probably more than just a simple commemoration of the legend of Demeter: they must also have had to do with procreativity throughout the world.

BDW

Acknowledgement

The graphic design for the new motif was produced by Mr P M Wilson, Department of Agricultural Engineering and Mechanisation, Edinburgh School of Agriculture; his enthusiasm and draughtsmanship are much appreciated.

Bibliography

Gibb, J A C (1962). The Presidential Badge of Office. *J & Proc IAgrE.* **18,** 62.

Guirand, F (1959). Greek mythology. *In New Larousse Encyclopaedia of Mythology.* Hamlyn. Paris.

Luttrell Psalter (1340). pp 43–45. British Museum. London.

Grain losses associated with combine harvesters operating on sloping land — performance changes over the past fifteen years

J A Pascal and A J Hamilton

Summary

DURING the periods 1967–1973 and 1979–1982, the Liaison Section of the Scottish Institute of Agricultural Engineering carried out a series of investigations into the effect on combine harvester performance of working on sloping land. Since the average size of combine harvesters had increased over the period of the investigation, the performance of machines from the two groups was compared. This showed that at a specific straw throughput, grain losses from the straw walkers had decreased by a much greater factor than the increase in separating area of that component. The addition of grain/straw separating attachments above the walkers was probably responsible for this. Grain losses from the sieves had decreased by approximately the same factor as sieve area had increased.

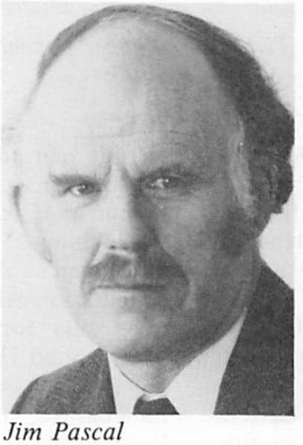
Introduction

The modern combine harvester is an expensive and relatively complex item of equipment and yet, with the exception of several very recent developments viz: axial-flow (Gray *et al* 1983a), cylinder system (Anon 1981), twin-flow (Anon 1982); it is, in effect a motorised version, with a cutting table attached, of the threshing mill developed in the mid-nineteenth century. To obtain the optimum performance from the threshing mill, it was necessary to place the machine in a level position before commencing work. Whether it was the stationary built-in type or the itinerant version (such a feature of the British farming scene in the second half of the nineteenth and first half of the twentieth centuries), installation engineers and travelling operators went to considerable lengths to ensure that this level situation was achieved.

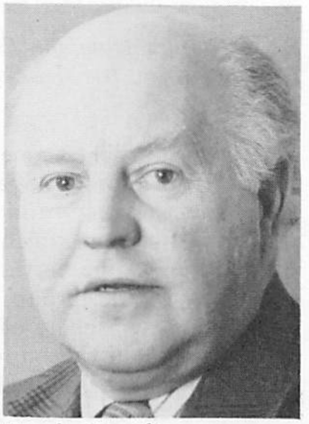
The combine harvester, however, is expected to operate in the field on a wide range of slopes, travelling uphill, downhill and across. In such circumstances the distribution of material in the separation system is extremely uneven and, therefore, the performance of the machine is likely to be adversely affected. A few manufacturers have produced specialised self-levelling machines for slope work but the increased retail price restricts their commercial application (Spiess 1979).

Jim Pascal and Sandy Hamilton are both in the Cultivations and Liaison Section of the Scottish Institute of Agricultural Engineering, Penicuik, Midlothian EH26 0PG.

Refereed paper: manuscript received 16 March and accepted in revised form 4 August 1984



Jim Pascal



Sandy Hamilton

To determine just how serious is the effect on combine harvester performance of working on sloping land, the Liaison Section at the Scottish Institute of Agricultural Engineering initiated in 1967 (Pascal and Provan 1967) an investigation into the degree of grain loss occurring in such situations. This investigation continued at intervals over the next fifteen years (Pascal and Provan 1969a; Pascal and Provan 1969b; Pascal and Robertson 1974; Pascal and Hamilton 1979; Gray *et al* 1983b), the series of trials falling into two distinct phases, 1967–73 and 1979–82. As the intervening period had seen the increasing use of grain loss monitors and several other minor alterations to the machines, eg the introduction of secondary separating devices interacting with the straw walkers and more, and higher, ribs on the sieves, it was decided to compare the results from the two periods to determine whether there had been any marked improvement in performance.

Procedure

In each of the years 1967, 1968, 1969, 1973, 1979, 1980 and 1982, one or more combine harvesters working on sloping land were assessed for grain loss (the makes and models of the machines examined in the various years are given in table 1). The sites were decided in consultation with the advisory services of the East of Scotland College of Agriculture, the West of Scotland Agricultural College and combine harvester suppliers in east and south-east Scotland.

Although minor modifications to the method of assessment took place over the years, the basic procedure

Table 1 Key to numbered curves on fig 1–6 giving makes, models and some details of machines investigated.

No on curve	*Machine*	*Year of test*	*Walker attachment*	*Loss monitor*
1	Aktiv M	1968	No	No
2	Bamford Volvo ST257	1968	No	No
3	Claas Dominator 96	1980	Overhead rakes	Yes
4	Claas Giant Matador	1967	No	No
5	Claas Mercator	1973	No	Yes
6	Fahr M1000	1973	No	No
7	Fisher Humphries Lely Victor	1969	No	No
8	Fiat Laverda M132	1982	No	Yes
9	International 841	1968	No	No
10	John Deere 530	1967	No	No
11	John Deere 965	1979	Overhead rotary tines	Yes
12	John Deere 985	1980	Overhead rotary tines	Yes
13	Massey-Ferguson 515	1967	Multi-flow unit at rear	No
14	Massey-Ferguson 515 (2nd m/c)	1967	Multi-flow unit at rear	No
15	Massey-Ferguson 625	1982	Multi-flow unit at rear	No
16	New Holland Clayson M89	1968	No	No
17	New Holland 8050	1980	No	No
18	New Holland 8060	1982	No	Yes
19	New Holland 8080	1982	No	Yes
20	Ransomes Cavalier	1969	No	No

remained substantially the same. It was based on the method developed at the National Institute of Agricultural Engineering for the testing of combine harvesters (Hebblethwaite and Hepherd 1955). Sieve and straw walker losses only were determined, it being considered that cutter bar and drum losses were not greatly affected by changes in gradient in the longitudinal direction (Anon 1979; Elrick 1982). Where possible, the performance was measured with the machine travelling uphill, downhill and on the level. On occasion, one or other of the above situations did not occur. In practice, operators try to avoid crossing fairly steep slopes, preferring to go straight up or down to keep manoeuvrability and control problems to a minimum; hence, only a few runs were recorded across the slope, so they have been omitted from this assessment.

At each site, areas of even growth and slope were selected. To determine cutting width, two stakes were placed 6 m apart at approximately the same distance from the standing crop. They were placed sufficiently far from the headland ($\nless$ 45 m) to ensure the harvester had attained a stable operating condition by the time they were reached. A further two stakes were similarly positioned approximately 20 m further along the crop face. The distance of each stake from the crop was measured before and after passage of the machine and the actual width of cut established. As a predetermined spot on the combine harvester passed the first stake, a cloth stretcher was inserted under the sieve discharge and removed when the same spot passed the second stake, the time taken to collect the sieve efflux being recorded. Similarly, as the spot on the machine passed the third stake, a cloth sheet was inserted under the straw walker discharge and removed when the spot passed the fourth stake, the time taken to collect the straw walker efflux again being recorded.

The material collected from the sieve discharge was transferred to a plastics bag. The straw walker efflux was weighed and the straw then carefully shaken out over the sheet and discarded. The material remaining after the straw removal was also transferred to a plastics bag. The bagged samples were taken back to the laboratory for final cleaning and grain loss weight determination. In order to increase the size of sample taken, the NIAE Mk I Rethresher (Hebblethwaite and Sharp 1962) was used in the first year and comparisons were made on both level and sloping land between this method and that described above. The results of this work showed that, while both collection methods returned similar results on level land, it was neither possible to work the rethresher satisfactorily on sloping land nor to transport the straw and grain loss laden sheets to the rethresher situated elsewhere (Pascal and Provan 1967).

The gradients were, in general, between 1 in 7 and 1 in 4 although the Claas Dominator 96 slope work was carried out at gradients between 1 in 9 and 1 in 11. Therefore, the results from this combine harvester should be treated with caution since it was operated on less steep ground than the other machines. In all but a few instances grain moisture contents were determined and no crops $>$ 24% wb have been included in this work. Where possible, three replicates or more were taken in each situation, but this could not always be accomplished owing to the high work rate of some combine harvesters (farm work was not interrupted for recording), to crop availability and to the nature of the field contours.

It is important to note that the performance of any one machine depends on the operator. Unless requested, no attempt was made by the experimental staff to advise the operator on his machine's performance and it would therefore be invidious to draw attention to the losses with any particular make of machine. Thus, results from combine harvesters (six in total) that were obviously badly set have not been included in the comparison of data.

For example, machines with the following setting faults were excluded:

(1) poor concave or drum speed settings which resulted in excessive straw break-up and subsequent grain separation difficulties on the walkers and sieves;
(2) conversely, under threshing results in the situation whereby the performance of the separating equipment is unduly enhanced;
(3) top sieves that had been set with small apertures and low air flows rather than the preferred larger apertures associated with higher air volumes.

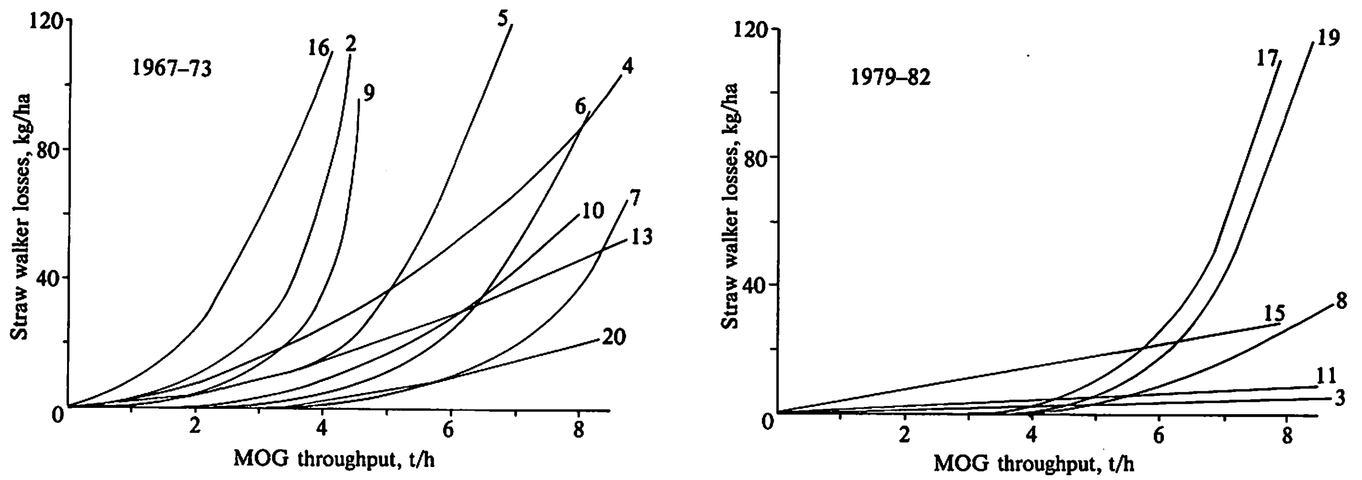


Fig 1 Grain loss and MOG throughput from straw walkers working uphill

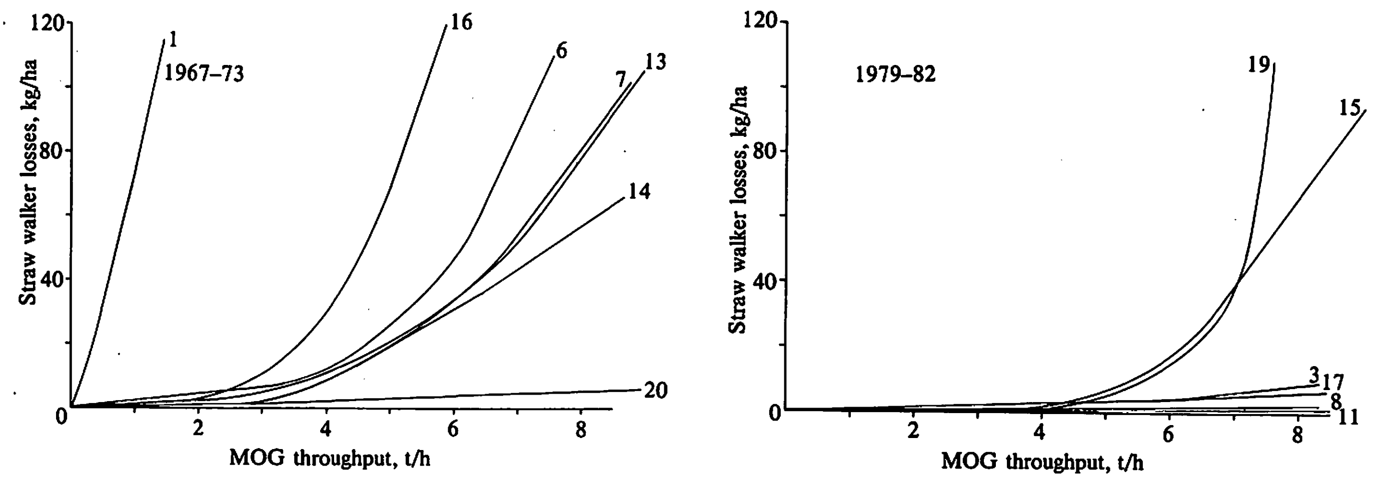


Fig 2 Grain loss and MOG throughput from straw walkers working downhill

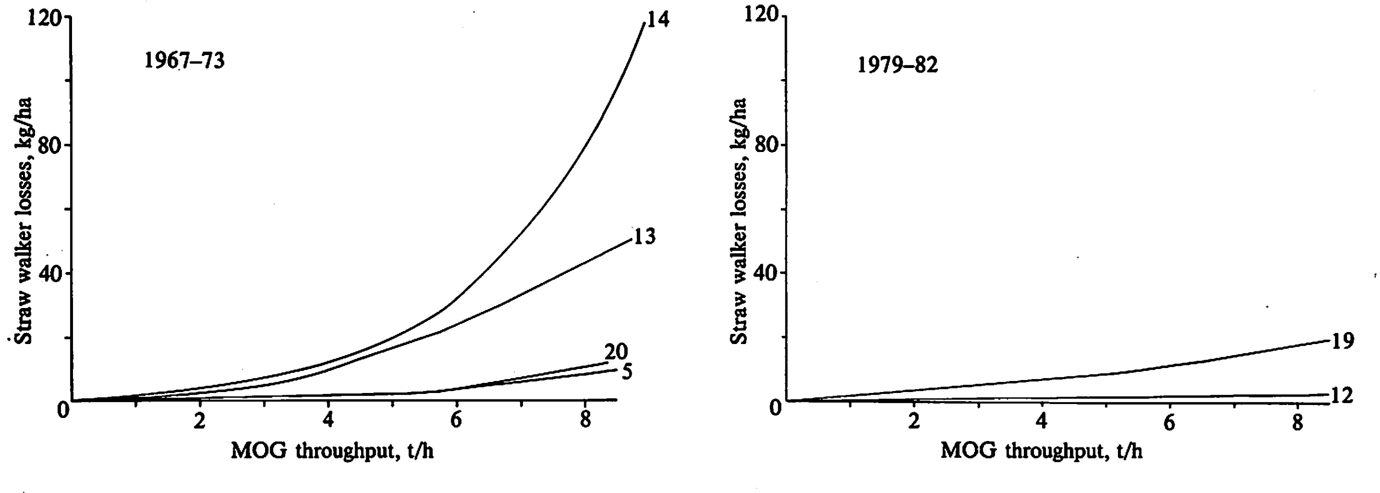


Fig 3 Grain loss and MOG throughput from straw walkers working level

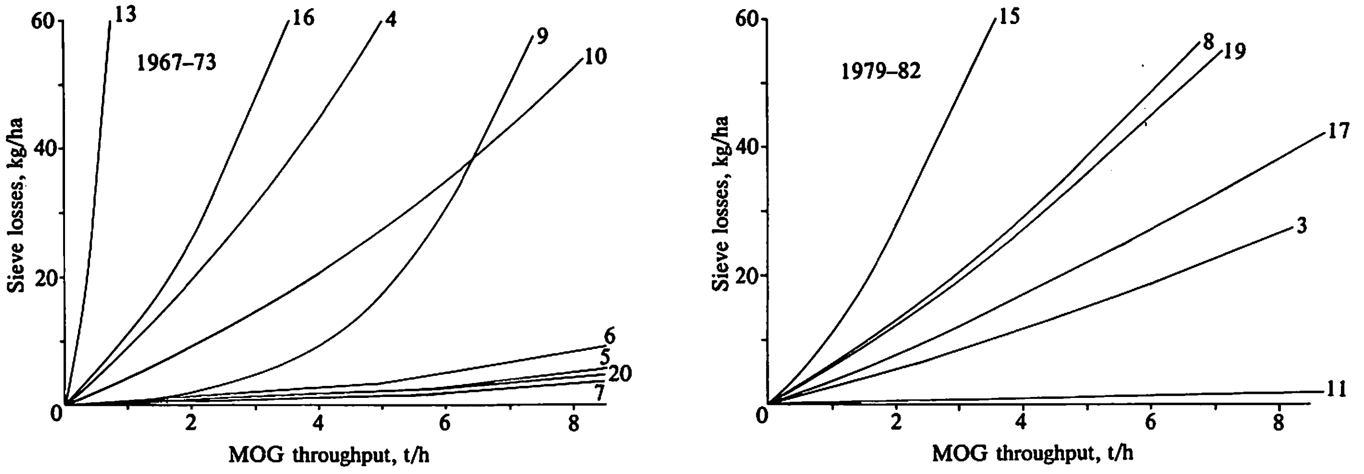


Fig 4 Grain loss and MOG throughput from sieves working uphill

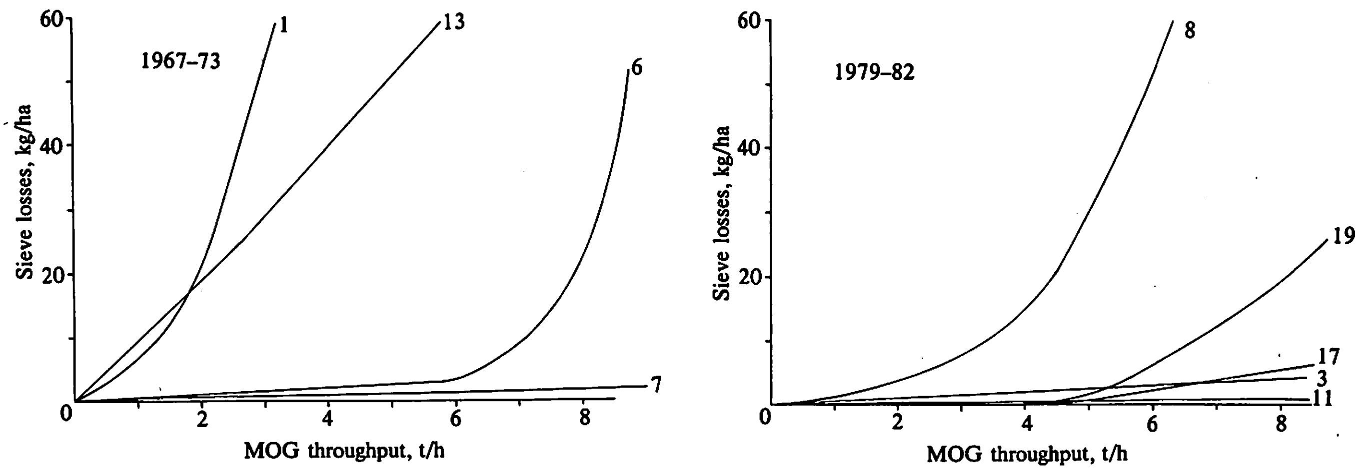


Fig 5 Grain loss and MOG throughput from sieves working downhill

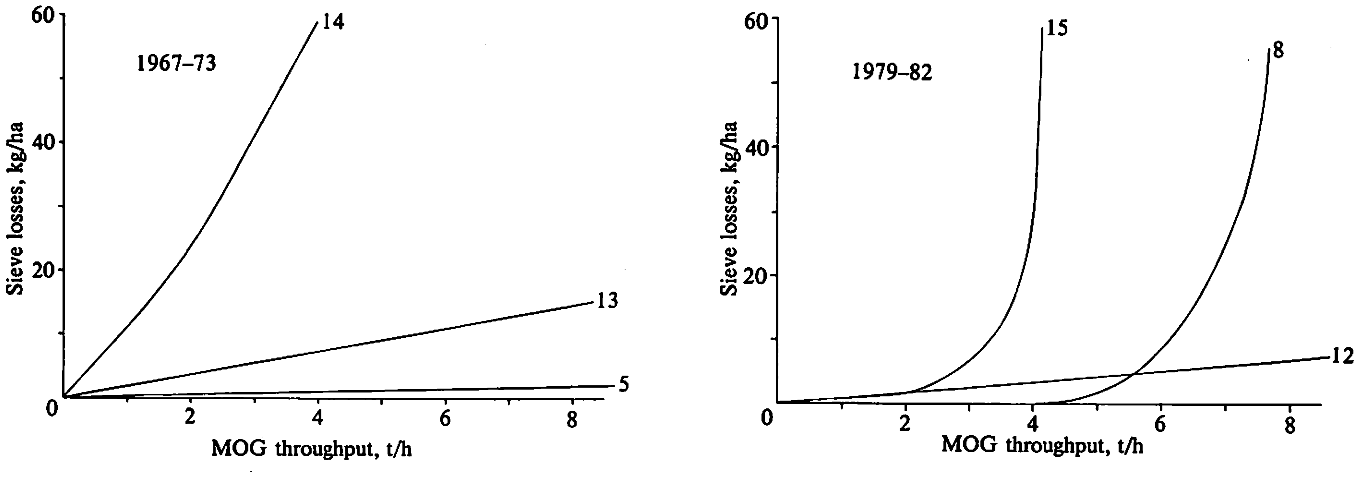


Fig 6 Grain loss and MOG throughput from sieves working level

Obviously all machines selected had to be in good working order.

The grain losses from each combine harvester on a particular type of slope, were plotted against the throughput of material other than grain (MOG). However, as most machines had different separating areas, it was not possible to make effective comparisons between such machines since their MOG throughputs at given grain loss levels were expected to be different.

To overcome this problem, the results were re-plotted with the MOG throughputs and grain losses adjusted on the assumption that each machine had separating areas of 4 m^2 for the straw walkers and 3 m^2 for the sieves. In order to avoid unwarranted changes in performance, it was assumed that all threshing and separating components had either been widened or narrowed to equate with the required separating areas. Grain loss levels at 3 and 6 t/h MOG throughput were then interpolated from the redrawn curves.

Results

For each topographic situation and for each given level of MOG throughput, the mean grain losses from combine harvesters of the two periods were compared statistically but no significant differences were recorded ($P \leq 0.05$). This was not unexpected since the trials were carried out over many different seasons in many different crops at many different locations. Taking these facts into consideration, it was considered that, outwith any statistical significance, the results still provided an indication of the differences in performance of combine harvester design over the stated period.

The average figures for straw walker and sieve grain losses obtained from runs carried out uphill, downhill and on the flat for each individual machine in each time period were plotted against MOG throughput, fig 1–6. Note that the key for the numbered curves in these figures is given in table 1. From the graphs of the uphill runs, fig 1 and 4, it is apparent that straw walker separation has improved to a considerable degree. There has also been an improvement in sieve separation but not to the same degree.

A fairly similar picture emerged with the downhill runs, fig 2 and 5. Here again, the 1979–82 figures showed an improvement over the 1967–73 results in both straw walker and sieve performance.

There was also some improvement on the level, fig 3 and 6, but it did not seem quite so marked in this case.

The results for each machine at interpolated MOG throughputs of 3 and 6 t/h are given in tables 2–7. These indicate that at the specific MOG throughputs of 3 and 6 t/h there has been a reduction of grain losses from the straw walkers of the later combine harvesters on both uphill and downhill runs and on the level. Similar loss reductions were obtained from the sieves on the downhill and level runs only. The performance of the sieves on the

Table 2 Comparative grain losses (kg/ha) from straw walkers with a standard area of 4 m^2 — uphill runs

1967–73

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
Bomford Volvo ST257	0.7	18.9
Claas Giant Matador	17.6	64.5
Class Mercator	11.4	157.3
Fahr M1000	1.3	25.6
F H Lely Victor	1.8	49.7
I H 841	0.1	112.4
John Deere 530	3.1	22.6
M F 515	8.9	29.2
N H Clayson M89	34.9	140.7
Ransomes Cavalier	1.1	7.4
Mean	8.1	62.8

1979–82

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
Claas Dominator 96	3.9	5.8
John Deere 965	0.1	1.2
Fiat Laverda M132	1.1	13.8
M F 625	12.4	35.0
N H 8050	0.2	10.3
N H 8080	1.3	77.9
Mean	3.2	24.0

Standard errors 3.98 (3 t/h) and 21.32 (6 t/h)

Table 3 Comparative grain losses (kg/ha) from sieves with a standard area of 3 m^2 — uphill runs

1967–73

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
Claas Giant Matador	24.1	48.3
Claas Mercator	0.7	1.3
Fahr M1000	1.1	2.3
F H Lely Victor	0.5	1.0
I H 841	0.5	1.1
John Deere 530	4.0	10.2
Ransomes Cavalier	34.0	98.4
Mean	9.3	23.2

1979–82

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
John Deere 965	0.6	2.0
M F 625	60.8	59.6
N H 8050	23.0	29.1
N H 8080	30.1	39.7
Mean	28.6	32.6

Standard errors 13.50 (3 t/h) and 18.80 (6 t/h)

Table 4 Comparative grain losses (kg/ha) from straw walkers with a standard area of 4 m^2 — downhill runs

1967–73

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
Aktiv M	139.2	313.2
Fahr M1000	6.0	56.3
F H Lely Victor	11.3	85.7
M F 515(A)	2.5	26.1
M F 515(B)	1.3	1.1
N H Clayson M89	4.0	56.3
Ransomes Cavalier	0.5	1.9
Mean	23.3	77.2

Standard errors 19.33 (3 t/h) and 53.06 (6 t/h)

1979–82

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
Claas Dominator 96	1.6	13.2
John Deere 965	0.8	1.4
Fiat Laverda M132	4.6	8.6
N H 8050	0.8	3.6
N H 8060	0.0	210.4
M F 625	9.9	70.1
Mean	3.0	51.2

Table 5 Comparative grain losses (kg/ha) from sieves with a standard area of 3 m^2 — downhill runs

1967–73

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
Aktiv M	26.9	187.2
Fahr M1000	0.0	2.9
F H Lely Victor	2.2	2.0
M F 515	23.4	50.8
Mean	13.1	60.7

Standard errors 7.10 (3 t/h) and 46.82 (6 t/h)

1979–82

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
Claas Dominator 96	2.9	2.5
John Deere 965	0.4	0.3
Fiat Laverda M132	7.4	80.8
N H 8050	2.1	7.1
N H 8080	1.0	58.3
Mean	2.8	29.8

Table 6 Comparative grain losses (kg/ha) from straw walkers with a standard area of 4 m^2 — level runs

1967–73

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
Claas Mercator	0.9	1.3
M F 515(A)	5.5	22.4
M F 515(B)	0.8	8.5
Ransomes Cavalier	1.4	5.2
Mean	2.1	9.4

Standard errors 1.09 (3 t/h) and 4.63 (6 t/h)

1979–82

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
John Deere 985	1.1	1.3
N H 8080	0.3	2.2
Mean	0.7	1.8

Table 7 Comparative grain losses (kg/ha) from sieves with a standard area of 3 m^2 — level runs

1967–73

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
Claas Mercator	0.9	0.5
M F 515(A)	46.1	56.4
M F 515(B)	13.8	27.3
Mean	20.1	28.1

Standard errors 13.41 (3 t/h) and 16.46 (6 t/h)

1979–82

Machine	*Grain loss, kg/ha, for MOG throughput* 3 t/h	6 t/h
John Deere 985	5.9	11.1
Fiat Laverda M132	0.1	1.7
M F 625	1.1	8.7
Mean	2.4	7.2

Table 8 **Changes in separating areas of combine harvesters that were evaluated**

Test runs	*Straw walker area*				*Sieve area*			
	1967–73 m^2	*1979–82* m^2	*Std error*	*Change* %	*1967–73* m^2	*1979–82* m^2	*Std error*	*Change* %
Uphill	3.91	4.94	0.48	+26.3	2.83	3.72	0.44	+31.4
Downhill	3.73	4.80	0.52	+28.7	3.33	3.68	0.44	+10.5
Level	4.24	5.44	0.33	+28.3	2.72	4.16	0.63	+52.9

Note: Mean separating areas taken from the combine harvesters operated on each type of slope

uphill runs had apparently become worse on the most modern machines; however, these later recorded measurements were made under difficult crop and weather conditions.

Determination of the mean separating areas and rates of work of the machines in the two periods while working uphill, downhill and on the level are given in table 8. The mean results indicated that while straw walker area had increased by around 28%, grain losses at a nominal 6 t/h MOG throughput had declined by 59%; whereas sieve area had increased by around 32%, grain losses at the same nominal throughput had declined by only 29%. Unlike recent work on generally level land (Rutherford 1983), these results suggest an improved performance of the straw walkers since grain loss levels have declined proportionately more than the area has increased. A possible explanation of this improved walker performance was that more of the combine harvesters in the later period were fitted with attachements to improve the grain/straw separation of the walkers. Examples were of modern John Deere and Claas machines being fitted, respectively, with cross-shakers and controlled rake tines over the walkers. Sieve grain losses have declined in the same proportion as sieve areas have increased.

Conclusions

1 The rate of work of combine harvesters at a given grain loss level appears to have increased considerably over the past fifteen years, by a much greater factor than the mean separating area.

2 Straw walker separating efficiency is much better with the latest machines, greatly reduced losses being obtained for similar straw throughputs. The fitting of specialised grain/straw separating attachments above the walkers may be responsible for this. It suggests also that greater straw throughputs are possible at a given grain loss level since MOG throughput governs combine harvester output (Dricot *et al* 1965).

3 Sieve separation has only improved to the same proportion as the sieve area has increased over the period investigated.

4 Since the data for the work are derived from summarised results taken over a wide range of crops and weather conditions and from many different makes and models of combine harvester, the conclusions should only be taken as a broad indication of the real situation.

Acknowledgement

The authors particularly wish to thank all those farmers, contractors and combine drivers who made their land, machines and time available for the work. Also the SIAE staff and vacation students who have assisted with the field work over a period of 16 years. The large number of persons involved in giving assistance makes it impossible to name them individually.

References

Anon (1979). The utilisation and performance of hillside combines. Occ Notes on Mechanisation No 281, Agric Dev advis Serv, Silsoe (unpubl).

Anon (1981). Cylinders replace walkers on super-size combine. *Power Farming*, Oct, pp 24–25.

Anon (1982). The New Holland TF42/44 combine harvester. *Power Farming*, Dec, pp 43–45.

Dricot C, Geortay G, Pletinckx A, Van Camp R, Vitlox O (1965). Etude de synthèse de la moissonneuse-batteuse. Ministère de l'Agriculture, Admin Rech Agron, Gembloux, Belgium.

Elrick J D (1982). How to choose and use combines. Publication No 88, Scott agric Colleges, Edinburgh. 40 pp.

Gray A G, Hamilton A J, Pascal J A (1983a). A comparison of the grain losses obtained with the International 1460 axial-flow combine and the International 953 conventional machine working on slopes. Dept Note SIN/351, Scott Inst agric Engng, Penicuik, July (unpubl).

Gray A G, Hamilton A J, Pascal J A (1983b). Grain losses from combine harvesters working on slopes 1980 and 1982. Notes for Mech advis Offr 190, Scott Inst agric Engng, Penicuik, 1983.

Hebblethwaite P, Hepherd R Q (1955). Detailed procedure for testing combine harvesters. Natn Inst agric Engng Tech Memo 121.

Hebblethwaite P, Sharp J R (1962). A rethresher for use in combine harvester testing. *J agric Engng Res* **7**, 161–164.

Pascal J A, Provan I H (1967). Grain losses from combine harvesters working on slopes. Notes for Mech advis Offr 10, Natn Inst agric Engng, Scott Stn, Penicuik.

Pascal J A, Provan I H (1969a). Grain losses from combine harvesters working on slopes. Notes for Mech advis Offr 21, Natn Inst agric Engng Scott Stn, Penicuik.

Pascal J A, Provan I H (1969b). Grain losses from combine harvesters working on slopes. Notes for Mech advis Offr 36, Natn Inst agric Engng, Scott Stn, Penicuik.

Pascal J A, Robertson T P (1974). Grain losses from combine harvesters working on sloping land — 1973. Notes for Mech advis Offr 97, Natn Inst agric Engng, Scott Stn., Penicuik.

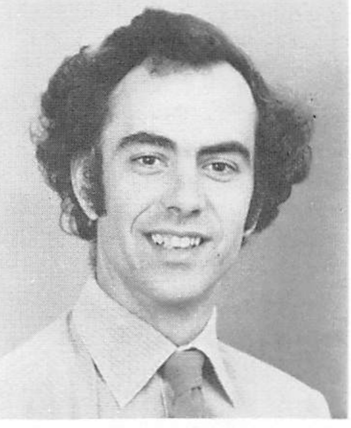
Pascal J A, Hamilton A J (1979). Assessment of the John Deere 965H combine harvester. Notes for Mech advis Offr 157, Scott Inst agric Engng, Penicuik.

Rutherford I (1983). The performance of combine harvesters, 1982. Occ Note No 319, Agric Dev advis Serv, Liaison Unit, Silsoe.

Spiess E (1979). Travail avec la moissonneuse — batteuse sur terrain declivés. *Technique Agricole*, **41**, 395–408.

Work-study on combine harvesters using automatic telemetry equipment

M B McGechan



Summary

LABOUR saving methods are described which employ automatic telemetry equipment for carrying out work-study to obtain data as the basis of Operational Research models of field mechanisation systems, particularly those related to cyclic transport. Examples of use for work-study during cereal harvesting are discussed. These were studies of combine speeds and work rates, lengths and causes of delays, driver's use of controls (and hence mental work-load), and threshing loss and consequential driving tactics on sloping ground.

1 Introduction

Palmer (1971) proposed that Operational Research (OR) studies should be carried out at the Scottish Institute of Agricultural Engineering (SIAE) to assess the potential value of agricultural engineering developments, particularly automatic control systems. In the interests of economy, these studies should be carried out before resources are committed to developing such systems. The studies should be based on real work-study data collected on commercial farms. Palmer considered that established techniques of survey and job analysis on farms often used observers wastefully, because brief observations are interspersed in long uninformative periods, and it was desirable at an early stage in the investigation that attention should be given to the design and use of labour-saving methods of recording. Some types of measurement, such as tractor running time or tractor speed, would be common to many investigations and it would be worthwhile to produce cheap specialised instruments which would record these measurements automatically.

Palmer (1984) has described the automatic telemetry system which was developed to carry out labour efficient work-study on commercial farms. The equipment was proved on a number of combine harvesters operating commercially during a survey in six cereal harvests. This paper describes four work-study exercises which were carried out concurrently in that survey. Two further studies also carried out concurrently, one on grain loss variability and the other on the relationship between combine harvesting work-days and daily rainfall, have been reported elsewhere (McGechan and Glasbey 1982, McGechan 1984a). This paper also discusses the type of OR study for which a large database is particularly valuable.

Dr Malcolm McGechan is in the Control Section of the Scottish Institute of Agricultural Engineering, Penicuik, Midlothian EH26 0PG.

Refereed paper: manuscript received 14 March 1984 and accepted in revised form 10 August 1984

2 Data measurement and handling

2.1 Automatic telemetry system

Mobile equipment on each field machine assembled data from a number of sensors into a single word ready for transmission. The base station interrogated each machine in turn during a 10 s cycle, recording data words from each machine sequentially on a single channel of a tape recorder. A clock in the base station produced a data word representing the time, recorded on the same channel at the beginning of each interrogation cycle.

2.2 Sensors

Sensors fitted to field machines were of three basic types. Firstly, a rotational sensor which was fitted, for example, to a combine harvester road wheel or threshing drum and consisted of either a toothed steel disc passing between a magnet on a magnetic switch (fig 1), or a proximity switch mounted close to the protruding bolts on a wheel. A series of pulses from the sensor was counted by the mobile equipment. On interrogation by the base station, a count was transmitted and the counter reset to zero. This count value could be considered to represent either the mean wheelspeed or the distance travelled by the machine throughout the interrogation interval. Secondly, a two-state sensor, consisting of a microswitch (fig 2) or a proximity switch mounted against a control lever, transmitted a value of zero or one to an input unit which both counted the number of changes of state of the lever during the interrogation interval, and recorded the state at the time of interrogation. Thirdly, a component such as a combine harvester steering linkage or cutter bar which could move over a range of positions, was monitored by an 'analogue sensor' which recorded the mean position during the interrogation interval. The output from a rotary potentiometer was fed through a voltage-to-pulse frequency converter so that it could be processed in a similar manner to the signal from rotational sensors.

Signals from acoustic grain loss monitors, which are already fitted to most combine harvesters, were tapped and fed to the telemetry system, via a purpose built interface.

Fig 1 Combine harvester wheel speed sensor based on a magnetic switch

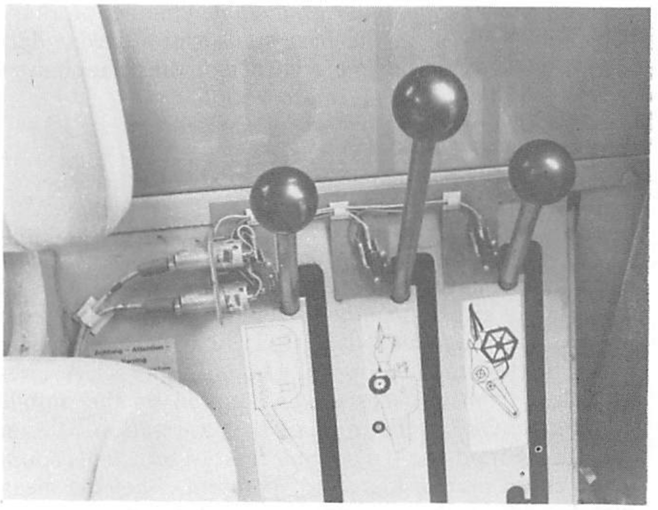


Fig 2 Microswitches fitted to combine harvester grain unloading, threshing, and cutting levers

2.3 Data processing
At the end of each day, the recorded data from each field machine and the base clock were transferred to a file on a mainframe computer and converted to character format, so that each line represented one transmission from one machine or a reading of the base clock.

Data transmitted by radio are inevitably subject to some losses or corruption before recording; such errors could be readily spotted by eye on inspection of a raw data printout. A 'data editor' was developed to enable most causes of data errors to be identified and corrupt data to be corrected where possible (McGechan 1983a). For example, an absent transmission followed by one in which all values are doubled is caused by the mobile equipment failing to recognise an interrogation, so the values from the second transmission are halved and entered in both positions.

Data files so produced were very large but, by adopting a 'record' system (Palmer 1981), information was stored in such a way that the data required for a particular study could be easily selected and read in a manner which was efficient in computer time.

2.4 Data analysis
A large data set describing a factor such as work-time or work-rate needs to be reduced in size before it can be used in an OR study. A simple summary of such a data set is its mean and standard deviation, but a fuller description may comprise some form of frequency distribution. The package program 'RGSP' (Rothamstead General Survey Program) (Beasley *et al* 1980) was found to be very well suited to reducing large data sets to tabular summaries such as means, standard deviations and numerical frequency histograms from which best-fit, mathematical function frequency distributions could be derived if necessary.

3 Cyclic harvesting and transport systems

Many operations in the production and particularly harvesting of arable crops can be regarded as closed circuit cyclic transport systems (Boyce 1971). Such systems are made up of transport units which move round a cycle of services. In cereal harvesting, for example, transport units may be tractors hauling trailers, and services are the grain drier or store and one or more combine harvesters. A transport unit must wait in a queue if a service is not ready to receive it, and these services can be idle part of the time awaiting the arrival of transport units.

A number of OR studies of such cyclic systems have been reported, for example, by Boyce (1973). The objective has been to determine the optimum number of services or transport units, either for maximum throughput or for minimum cost. So-called 'Monte-Carlo' simulation techniques have been employed in most studies. In order to represent the random variation in work times and delay times in the system, the time for each element of an operation has been selected by means of a random number generator from a frequency distribution.

Before constructing any type of model of a cyclic transport system, it is necessary to carry out field studies of work times for each element of the system. Sufficient data must be collected to derive frequency distributions of these work times (Dumont and Boyce 1972). In the past, such data have been collected by labour intensive observation methods (Gibbon 1972 and 1973, Parke 1972). It was expected that the automatic telemetry equipment would be well suited to collecting large quantities of data of this type, both from individual field machines and from a number of machines collaborating in the same operation. Cyclic transport system studies were expected, therefore, to be a major part of the OR program at the Scottish Institute of Agricultural Engineering (McGechan 1977).

4 Examples of work-study applied to the grain harvest

4.1 Combine harvester work-rates

4.1.1 Methods of summarising work-rate data

Work rates, in the form of forward speeds and times to cut

100 m of crop, were reported (Morrison 1980, Webb and McGechan 1982) as frequency histograms generated by the package program RGSP (eg fig 3). Information was processed only for periods when the combine harvester was in work, as indicated by a engagement of the threshing and cutting systems, the cutting bar being lowered and the combine harvester moving.

4.1.2 Relating data to mathematical distributions

It was expected that there would be a top limiting value for combine harvester cutting speed, giving distributions negatively skewed for wheelspeed and positively skewed for time to cut 100 m. In practice, frequency histograms, even for one machine on one day, while bearing a tentative relationship to the expected shape, often had other prominent features such as two or more peaks with troughs in between (fig 4). A gamma distribution, fitted to such data using a program developed by Dumont and Boyce (1972) (fig 4) differed in many respects from the frequency histogram it was intended to represent. For Monte-Carlo type simulations it would be better to select speeds or work-rates from a data histogram rather than from a derived mathematical distribution which differs considerably from the data.

4.1.3 Utility of data

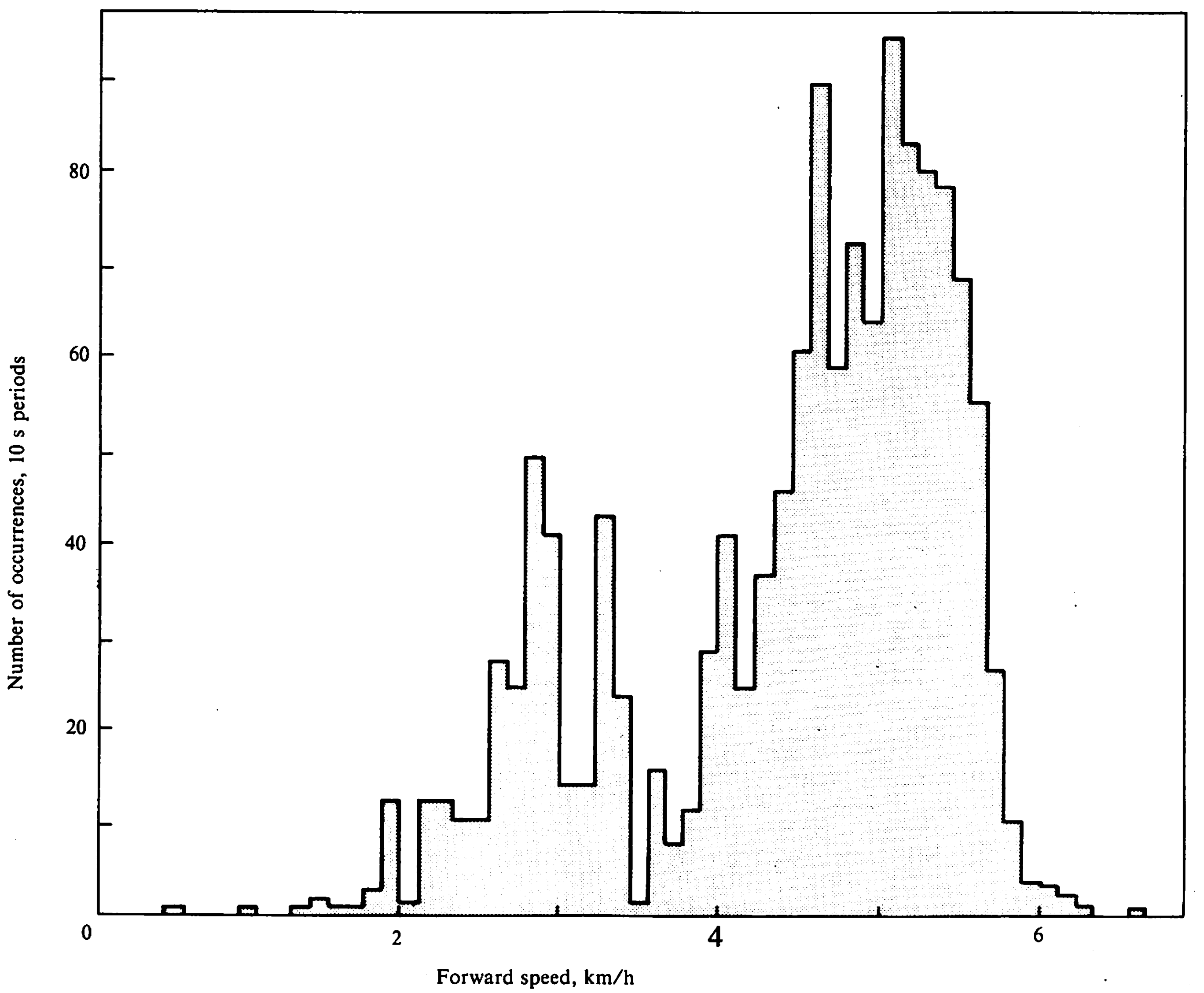
This work-study exercise produced, from individual machines, data of the type required for constructing cyclic transport system models, and demonstrated the value of automatic equipment as a labour saving means of collecting this type of data. In practice, no OR study of cereal harvesting as a cyclic system was carried out, nor was data collected from transport tractors collaborating with combine harvesters in such a system. The data have, however, been of interest as a general indication of combine harvester work rates, for a study of the speed limitations of combine harvesters (see Section 4.3).

4.2 Analysis of delays during combine harvesting

4.2.1 Methods of summarising data

In many OR studies, it is more important to know the overall or average work rate rather than the spot work rate. Delays arising from several causes account for differences between these two work rate parameters. The term 'field efficiency', expressed as a percentage, is commonly used to describe the relationship between overall work rate and spot work rate. Field efficiency has been defined by ASAE (1970) as the ratio of spot work-time to overall work-time. In the present study (McGechan 1982), numerical records representing

Fig 3 Frequency histogram of combine harvester forward speeds (one combine harvester on one day)



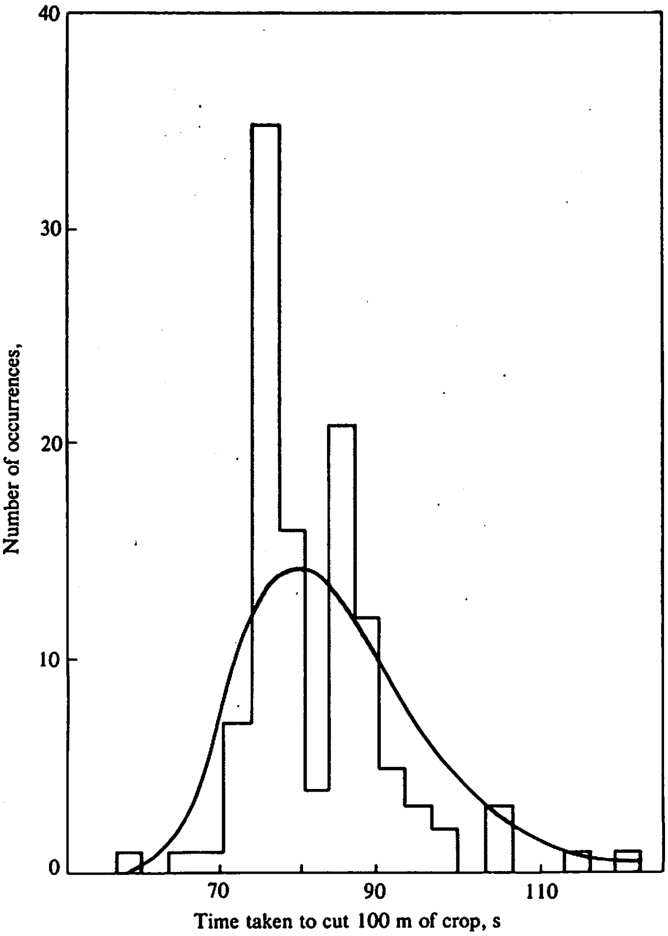


Fig 4 Gamma distribution fitted to a frequency histogram of time to cut 100 m of crop (one combine harvester on one day)

combine harvesters at work were converted to a descriptive timetable of events (fig 5). Where sensor indications made it possible, delays were attributed to causes such as turns at the end of rows and unloading grain. Assessments were made as to whether grain had been unloaded on the move or not. The delays in each daily timetable were summarised as a field efficiency value, and the package program 'RGSP' was also used to present a summary of the lengths and causes of delays to each machine.

4.2.2 Results in relation to transport systems

Data were analysed from four combine harvesters on different farms over three seasons, totalling 57 machine days. The mean times lost due to turning, unloading grain and other factors were, respectively, 14.5%, 9.9% and 4.6% of the total work time. The mean field efficiency was 70.9%.

There was a clear relationship between field efficiency and the intensity of the transport system employed to lead grain from the combine harvesters (fig 6). On some days on two of the farms (farms 1 and 2), low values of field efficiency were observed and only a small percentage of grain was unloaded on the move. All the other farms employed sufficient transport units to unload about 80% of grain on the move, giving a mean field efficiency of 73.6%. Audsley and Boyce (1974) and Philips and O'Callaghan (1974) assumed values of 75% and 70%, respectively, in their OR models of the cereal harvest. The data from this study indicate that transport systems with normally sufficient capacity to unload grain on the move have been assumed in both these OR models.

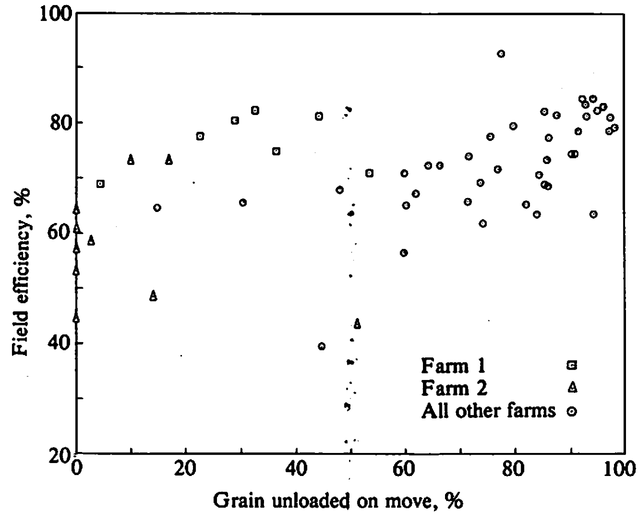


Fig 6 Field efficiency against percentage of grain unloaded on the move (each point represents one combine harvester on one day)

4.3 Driver's use of controls

4.3.1 Purpose of study

Surveys carried out by mechanisation advisers in England and Wales (NAAS 1969, Rutherford 1977) showed that typical average combine harvester speeds were very much lower than the optimum speeds suggested by simulation models, such as those of Audsley and Boyce or Philips and O'Callaghan. This indicates that expensive equipment is often grossly under-utilised. Two factors could account for this discrepancy.

1) The mental workload imposed by the driving task of adjusting the three main combine harvester controls, ie steering, cutter bar height and forward speed, might be a limiting factor preventing combine harvesters from being driven faster.
2) Drivers may be under the mistaken impression that threshing losses will rise to an unacceptable level if they drive faster.

In this study (McGechan 1983b), evidence of the influence of the mental workload on combine harvester speeds has been examined. For this purpose, mental workload was assumed to be related to the frequency of adjustment of the three main combine harvester controls.

4.3.2 Instrumentation to measure driver's use of controls

Instrumentation to determine the number of adjustments made to the forward speed and cutter bar height involved the use of microswitches on the control levers. Both forward speed and cutter bar height were controlled by a hydraulic system and remained at a constant setting unless adjusted by their lever; the lever was actuated in one direction to raise the setting and in the other direction to lower it.

Compared with the wheel speed and cutter bar height controls it was difficult to produce a meaningful indication of the number of adjustments to the steering, or even to define what was meant by a steering adjustment. Steering reversals have been used as a measure of mental workload in a number of applied psychology studies of road driving, for example, Kimball *et al* (1971), McLean and Hoffman (1971). The measure used in this study was the number of reversals in direction of the steering wheel movements, where the movement was in excess of about 5° of arc.

```
DAY HOUR MINUTE SECOND

24 10 11 46    5565 TABLE UP
                    TURNING
                               WORK STOPPED AFTER CUTTING  155.5 METRES IN  2.0 MINUTES

24 10 12  6    5580 WORK STARTED
                               WORK STARTED AFTER TRAVELLING  14.6 METRES IN  0.3 MINUTES DELAY  16.8% OF CUTTING TIME
                               SINCE LAST TURN CUT 155.5 METRES IN   2.0 MINUTES
                               TOTAL DELAY   0.3 MINUTES    16.8% OF CUTTING TIME
                               NO-TURN-OR-UNLOAD DELAY   0.0 MINUTES     0.0% OF CUTTING TIME
                               TURN DELAY  16.8% OF CUTTING TIME

24 10 13 55    5727 UNLOADING
                               UNLOADING STARTED AFTER    1.8 MINUTES

24 10 16  4    5883
                               CUT 155.9 METRES WHILE UNLOADING FOR  2.1 MINUTES
                               SINCE LAST UNLOAD CUT 1000.6 METRES IN  13.4 MINUTES
                               TOTAL DELAY   3.5 MINUTES    26.0% OF CUTTING TIME
                               NO-TURN-OR-UNLOAD DELAY   0.0 MINUTES     0.0% OF CUTTING TIME
                               UNLOAD TIME  16.1% OF CUTTING TIME

24 10 18 53    6087 TABLE UP
                    TURNING
                               WORK STOPPED AFTER CUTTING  507.0 METRES IN  6.8 MINUTES

24 10 19  3    6094 WORK STARTED
                               WORK STARTED AFTER TRAVELLING   6.9 METRES IN  0.2 MINUTES DELAY   2.5% OF CUTTING TIME
                               SINCE LAST TURN CUT 507.0 METRES IN   6.8 MINUTES
                               TOTAL DELAY   0.2 MINUTES     2.5% OF CUTTING TIME
                               NO-TURN-OR-UNLOAD DELAY   0.0 MINUTES     0.0% OF CUTTING TIME
                               TURN DELAY   2.5% OF CUTTING TIME
```

Fig 5 Part of a descriptive timetable of a combine harvester cutting a crop

4.3.3 Presentation of results

Using the package program RGSP, histograms were produced of the number of adjustments to each of the controls individually and in total per 10 s period (fig 7). Of the three main combine controls, steering was adjusted most frequently, forward speed least frequently. There were peaks in the distributions at 3–5 adjustments in 10 s (0.3–0.5/s), with maxima around 14 adjustments in 10 s (1.7/s).

4.3.4 Interpretation of results

Workers in applied psychology and ergonomics consider that there is a maximum rate at which the human brain can process information. This limit varies from task to task, but is highest for a skilled task such as driving, typically about 5 bits/s. When manual motor actions are used as a measure of the rate of processing of information by the brain, adjustment must be made for uncertainty in the information on which a decision is based, which increases the time taken to make the decision. To allow for this, the observed rate of adjustment of controls must be multiplied by a factor $z = \log_2 (n+1)$ (see Welford 1968). The parameter, n, represents the choice of control adjustments, in this case 6 (2 directions for each of 3 controls), giving a value of 2.81 for the factor, z. Both the observed mean total rate of processing information and the maximum rate, when multiplied by this factor, were below the limit of 5 bits/s. This suggests that combine harvester speeds are not limited by driver's workload.

In discussing the results of his most recent survey of combine harvester speeds, Rutherford (1983) attributed low speeds to the very low level of threshing loss expected by farmers of modern large combine harvesters. This suggests that low combine harvester speeds arise from factors other than limitations of driver's mental workload.

This study provided a useful demonstration of the value of the telemetry system for observing a driver's use of his controls but, in the case of the combine harvester, produced only tenuous evidence that speed is limited by factors other than driver's workload.

4.4 Grain losses and driving tactics on sloping ground

It is widely assumed that threshing losses of a conventional straw-walker combine harvester are greater

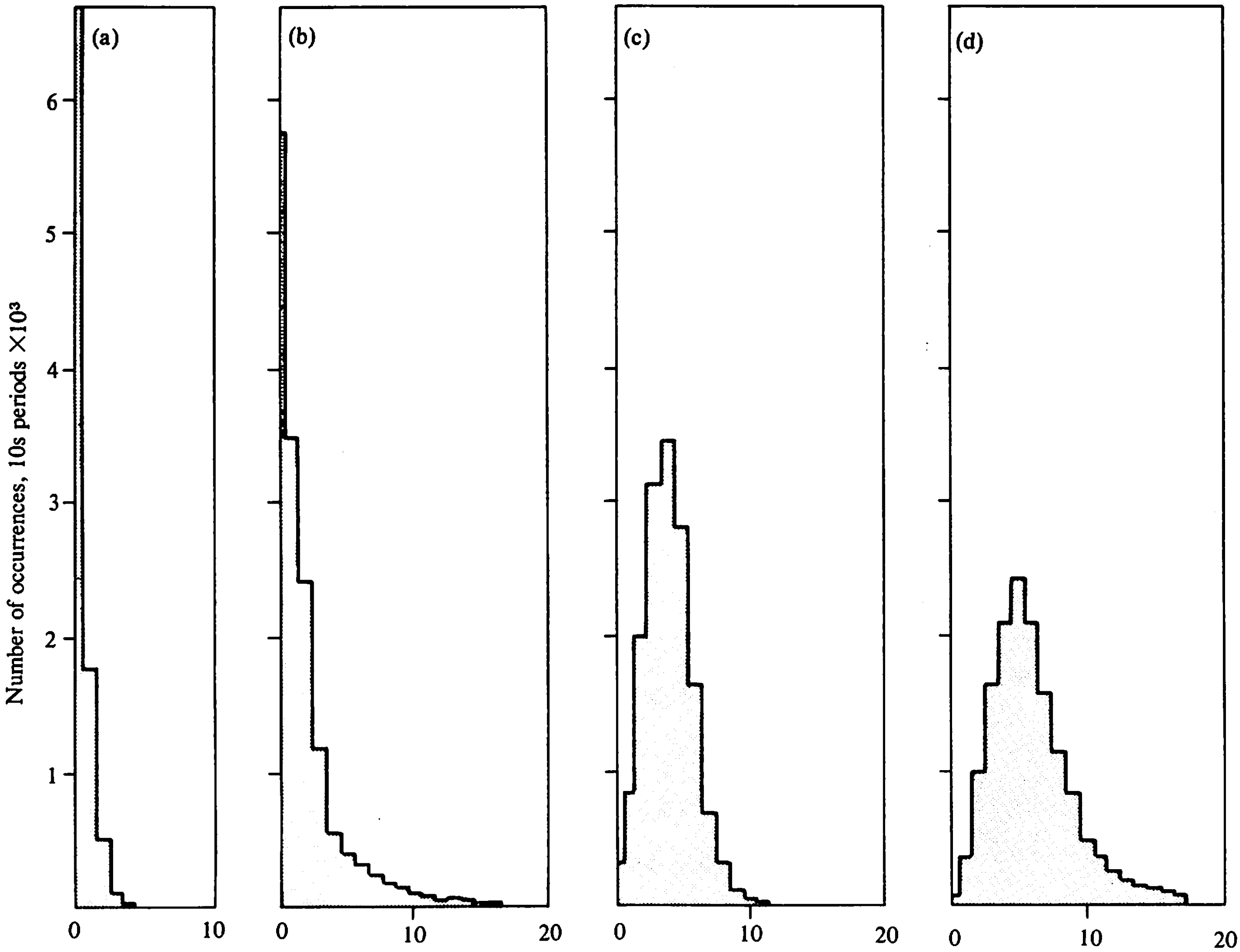


Fig 7 Frequency histograms of combine harvester control adjustments: a) forward speed control lever: b) cutter bar height control lever: c) steering wheel reversals: d) total: (one combine harvester working for ten days)

on sloping ground than on level ground, particularly if the combine harvester is driven along the side-slope rather than straight up and down the gradient. There may also be differences in loss levels between the uphill and the downhill direction. Small quantities of data describing losses on slopes have been collected by labour-intensive methods (Pascal *et al* 1967–73). The telemetry survey provided a source of large quantities of such data (McGechan 1984b), since the combine harvesters were fitted with both acoustic loss monitors and inclinometers which measured slope in both transverse and longitudinal planes. It also provided some information about tactics adopted by drivers to reduce threshing losses on slopes. On one farm in particular, combine harvesters were studied while working in hilly fields.

The loss monitors consisted of three acoustic sensors fitted, respectively, under the straw walkers, under the sieves and above the sieves in the air stream from the fan. The recorded signal from each monitor sensor was an uncalibrated value representing grain loss over a 10 s period.

Analysis of data showed a standard deviation of transverse slope smaller than that for longitudinal slope, indicating that the combine harvester driver was cutting up-and-down in preference to across slopes. Combine harvester speeds decreased significantly with increase in slope in either direction (fig 8). Straw walker losses, both per unit time and per unit area, generally increased with increase in transverse slope. In contrast, these losses appeared to decrease with increase in longitudinal slope, either because of the lower combine harvester speeds or because a smaller proportion of material struck the monitor sensors on slopes giving a lower indicated loss. Sieve losses decreased with increase in slope in either plane, while fan air losses sometimes increased and sometimes decreased with slope.

If the assumption that losses at the straw walkers greatly outweigh the other losses is correct, results indicate that the drivers were wise in attempting to cut up-and-down rather than across slopes. They were also adjusting or even over-adjusting their speeds appropriately on slopes in both planes, possibly using the displayed loss monitor reading to indicate the appropriate speed. Some farmers claim that acoustic monitors are of considerable value as a guide to speed when operating on hilly ground. Results of this study suggest that this view may be correct.

5 Concluding comments

Some general comments can be made from experience at

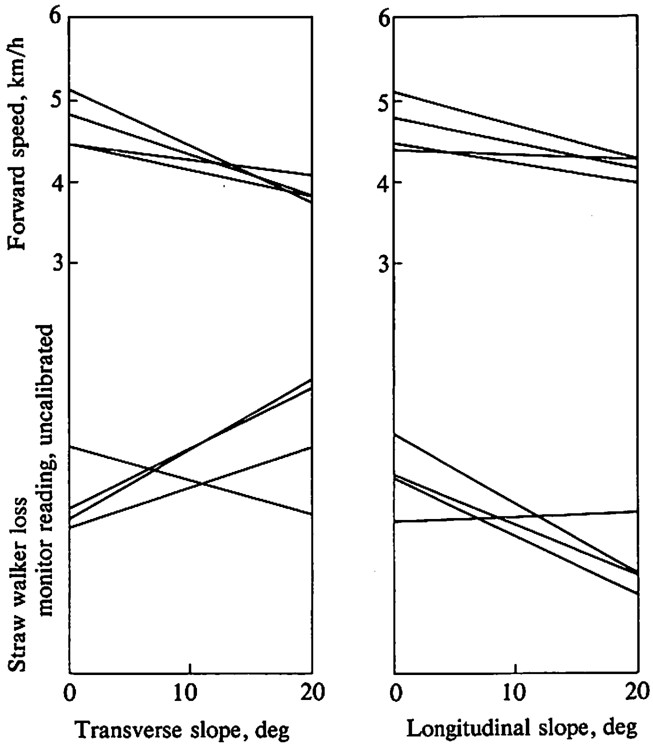


Fig 8 Combine harvester forward speeds and indicated threshing losses on sloping ground (each line represents one combine harvester on one day)

attempting work-study with automatic telemetry equipment.

Development of the equipment was a very difficult task. In the early stages, many faults arose both in the electronics of the telemetry system and with sensors. The combine harvester survey and the twin objectives of testing and further developing the equipment to a reliable stage, and carrying out useful work-study. Extensive servicing of equipment was carried out on the combine harvesters on wet days during the harvest and during the remainder of the year when the machine was idle. It was feasible to carry out such equipment development on farmers' combine harvesters, but not on tractors which were in continuous use. The equipment was found to be more suited to collecting detailed information from a small number of machines rather than a little from a larger number (such as wheelspeed alone from a number of transport tractors). Technology has advanced during the period in which the equipment was being designed and developed, such that it would now be feasible to record locally on each machine; this would avoid the problems associated with radio transmission. However, the ability to identify faulty sensors from the base station would be lost, and there would be an additional labour requirement for changing recorder tapes on each machine.

While automatic equipment provided very detailed data in large quantities, enabling a number of work-study exercises to be carried out concurrently, it did not entirely remove the need for human observers. The data pose a number of questions which might have been answered if observers had been present, such as whether a distribution with two peaks is really the sum of two distinct distributions with different means, arising in different fields or crops, at different times of day or with different drivers. In practice, problems with equipment made such severe demands on the manpower available that scope for observation was very limited.

While cereal harvesting was a very suitable operation in which to do equipment development work and to collect detailed data of various types, it was less suitable for proving the value of large quantities of data for OR. Cyclic transport systems are the type of OR study for which such quantities of data are most valauble, but in cereal harvesting the costs of transport are small relative to other items such as the capital cost of the combine harvester and the value of the grain losses. Also, it did not prove feasible to collect data from transport tractors associated with the combine harvesters. Therefore, an OR study of a grain harvest transport system has not been attempted.

The value of automatic telemetry equipment for some useful work-study exercises has been demonstrated, but a case for collecting data in this manner for OR studies of field mechanisation systems has yet to be made.

Acknowledgement

I wish to thank Dr A Knight of Napier College, Edinburgh for advice about interpreting drivers' use of controls data as a measure of mental work-load.

References

ASAE (1970). Agricultural machinery costs and use. Am Soc agric Engng Data: ASAE D2301, *Agricultural Engineering Yearbook.*

Audsley E, Boyce D S (1974). A method of minimising the cost of harvesting and high temperature grain drying. *J. agric Engng Res*, **19**, 173–189.

Beasley J D, Church B N, Yates F (1980). *The Rothamsted General Survey Program (Parts 1 and 2).* Rothamsted Experimental Station, Harpenden, Herts.

Boyce D S (1971). The simulation of discrete transport systems. Dep Note DN/SY/114/1951. Natn Inst agric Engng, Silsoe (unpubl).

Boyce D S (1973). Studies of silage systems for harvesting, transporting and loading of bunker silos. Dep Note DN/SY/346/1951. Natn Inst agric Engng, Silsoe (unpubl).

Dumont A G, Boyce D S (1972). Method of fitting statistical distributions to observed work times for agricultural unit operations. *J agric Engng Res*, **17**, 295–302.

Gibbon J M (1972). Field studies of closed circuit transport systems for silage productions. Dep Note DN/SY/185/1951. Natn Inst agric Engng, Silsoe (unpubl).

Gibbon J M (1973). Further field studies of closed circuit transport systems. Dep Note DN/SY/329/1951. Natn Inst agric Engng, Silsoe (unpubl).

Kimball K A, Ellingstad V S, Hagen R E (1971). Effects of experience on patterns of driving skill. *J Safety Res,* **3**, 129–135.

McGechan M B (1977). Operational research studies of the use of field machines: a discussion of terminology, review of literature and proposals for exploitation of automatic survey equipment. Dep Note SIN/230. Scott Inst agric Engng, Penicuik (unpubl).

McGechan M B (1982). Work timetables and analysis of delays during combine harvesting. Dep. Note SIN/358. Scott Inst agric Engng, Penicuik, December (unpubl).

McGechan M B, Clasbey C A (1982). The benefits of different speed control systems for combine harvesters. *J agric Engng Res*, **27**, 537–552.

McGechan M B (1983a). An editor for automatic telemetry survey data correction. Dep Note SIN/335, Scott Inst agric Engng, Penicuik (in preparation).

McGechan M B (1983b). Work study investigation of driver's use of controls on combines. Dep Note SIN/378. Scott Inst agric Engng, Penicuik (unpubl).

McGechan M B (1984a). Information used for testing combining work-days criteria. Dep Note SIN/396. Scott Inst agric Engng, Penicuik (unpubl).

McGechan M B (1984b). Analysis of data obtained in telemetry survey on combine grain loss and drivers' tactics on sloping ground. Dep Note SIN/389. Scott Inst agric Engng, Penicuik (unpubl).

McLean J R, Hoffman E R (1971). Analysis of driver's control movements. *Human Factors*, **13**, 407–416.

Morrison C I (1980). Some results from an automatic survey of the 1978 cereal harvest. Dep Note SIN/269. Scott Inst agric Engng, Penicuik (unpubl).

NAAS (1969). The utilisation and performance of combine harvesters. Farm Mechanisation Study No. 18. Min Agric Fish Food.

Palmer J (1971). Project planning for application of control engineering to agriculture. Dep Note SIN/71. Scott Inst agric Engng, Penicuik (unpubl).

Palmer J (1981). Procedures for analysing automatic survey data. Dep Note SIN/325. Scott Inst agric Engng, Penicuik (unpubl).

Palmer J (1984). Automatic collection of data on practical use of field machines. Paper No 84 — 1629. Am Soc agric Engng Winter Meeting, New Orleans.

Parke D (1972). A study of the use of equipment and the rate of work of a multiple unit forage harvesting system. Dep Note DN/SY254/1951. Natn Inst agric Engng, Silsoe (unpubl).

Philips P R, O'Callaghan J R (1974). Cereal Harvesting — a mathematical model. *J agric Engng Res*, **19**, 415–433.

Rutherford I (1977). Giant combine harvesters. Machinery Performance Note No. 121, Agric Dev advis Service Liaison Unit, Silsoe, (unpubl).

Rutherford I (1983). The performance of combine harvesters 1982. Occasional Note No. 319, Agric Dev advis Service Liaison Unit, Silsoe (unpubl).

Pascal J A, Provan I H, Robertson T P (1967–73). Grain losses from combine harvesters working on slopes. Notes for Mech advis Offr 10, 21 36 and 97. Scott Inst agric Engng, Penicuik (unpubl).

Webb D J, McGechan M B (1982). Some work rate data from an automatic survey of the 1977–80 cereal harvests. Dep Note SIN/331. Scott Inst agric Engng, Penicuik (unpubl).

Welford A T (1968). *Fundamentals of skill*. Methuen.

Feed preparation on the farm

A J Summerfield

Introduction

BEFORE embarking on a mill and mix operation or revamping an existing one, the main considerations are: buildings; intake; grinding*; mixing/weighing*; pelleting*; feed contamination; quality control. The most important aspects in any comparison with a feed compounder are asterisked.

Buildings

When building new premises, pvc coated steel should be considered as it provides a longer life than asbestos. Request 15% roof lights instead of the standard 10% and, where possible, plan for single span steel construction building with room for development on 2 sides. Use "the no gutter principle" and save on future building maintenance because it is much easier to construct a gulley at ground level and sweep it, than to hang on a ladder 15 m up to get out a bird's nest! In addition, ensure adequate space for expansion and make sure that yards/roads can cope with 30-40 tonne articulated lorries. Hence, do not sandwich your plant into a spare building or corner of the farm yard.

Intake

Ensure that the intake will cope with the discharge rates of a modern lorry working at speed, ie, no less than 40 t/h on grain, but half that rate when handling meal. With EEC drivers' hours restrictions, waiting time charges may be incurred if it is too slow unloading.

The pit should be covered from the weather to prevent expensive ingredients getting wet. A strong grille should be used to protect the intake machinery — it may catch the spanner that the tractor driver dropped! Bins, where possible, should be steel and self-emptying.

Buy elevators and conveyors that are cased in steel, of proven design and, preferably, British — to avoid future spares problems, although certain Continental suppliers may be fairly well represented in your area.

Tony Summerfield is Production Manager for Colborn-Dawes Nutrition Ltd, Heanor Gate Industrial Estate, Heanor, Derbyshire.

This paper was presented at the Scottish Branch Annual Conference entitled "Preparing feed for dairy and beef" and held at Dunblane Hydro Hotel on 15 February 1984.

Grinding

Most on-farm grinders tend to have grinding and blowing components all mounted on one shaft. The cyclones which are used tend to be inefficient — approximately 1½ to 5% meal loss — and, in addition to the losses themselves, there is added the adverse effects on the environment.

It is recommended that grinding should be associated with an expansion box principle, dust filtration, and mechanical conveying. Grinding and dust loss would then be ½-1%. Purchase a well proven grinder for which spares are readily available.

Extract guarantees of throughout from your supplier, based on the moisture content of your commodities, ie most grinding outputs are based on 14% moisture for dry wheat (table 1). Plant outputs, for planning purposes, are given in table 2. The capacity should match weekly demand in five days.

Table 1 Variation of mill output with grain moisture content for a screen size of 3 mm

Moisture content, %	*Specific output, kg/kWh*
13	66.0
15	56.6
17	48.7
19	40.8

Mixing/weighing

The compounder will probably have a mixer with a 1: 10,000 accuracy, mixing 1-3 t per 3½ min. There are four main methods of mixing.

(1) Square chain and flight mixer
It looks like an old-fashioned muck spreader sealed at both ends, but it is not suited to modern ration mixing and the mixing time is 20 min.

(2) Fountain or vertical mixer.
Certain makes which have a sheath over part of the centre auger are preferable because they give a better dispersion and mix quicker, ie 8 minutes. Without a sheath, mixing takes 12-15 min. This type of mixer is not suitable for liquid addition (ie fats, water, molasses), and is not ideal for critical diets (ie pig starter, etc) because of the accuracy of ingredient dispersion.

(3) Horizontal mixer
This type is the most expensive but the best. It has the shortest mixing time, 3½-4 min and is up to 99.9% self-emptying. It is suitable for liquid addition (ie molasses, oil/fat, water),

Table 2 Approximate weekly and annual outputs from different sizes of hammer and roller mills, based on 40 hours use per week (8h x 5 days) and 50 weeks per year

Mill power, kW	*Mill output, t/week*			*Mill output, t/year*		
	Hammer mill for pigs/poultry		*Roller mill for cattle*	*Hammer mill for pigs/poultry*		*Roller mill for cattle*
	**P*	**A*		**P*	**A*	
2	4	8	11	200	400	600
4	8	14	18	400	700	900
6	12	20	36	600	1000	1800
8	17	25	48	850	1250	2400
11	27	-	-	1350	-	-
15	35	-	-	1750	-	-
19	40	60	-	2000	3000	-

**P = Pneumatic conveying and 3 mm screen*
**A = Auger conveying and 3 mm screen*

and is very accurate, giving a dispersion ratio of 1:10,000. Only a low head room of 1 to 1½ m is required compared with one of 3 m for a vertical mixer.

(4) Proportioning

This loose form of mixing has severe limitations of flexibility and quite often results in higher cost rations. The limited number of channels, usually six, restrict the variety of ingredients which can be included in the ration and increases the necessity of using concentrates which defeat the original purpose of home compounding, namely a complete knowledge of the raw materials. Proportioners require constant recalibration, virtually with each load of grain because of differing densities.

The volumetric proportioning systems can be reliable providing that they are calibrated individually at least once per week, or when every load of newly delivered ingredients pass through them.

Accuracies on a well maintained and calibrated plant can be from ±2% to ±7%, unless special equipment is installed. The addition of mineral supplements is difficult. It is bad practice to pass mineral supplements through a grinder, as not only can vitamins be destroyed by grinder heat, but beater wear is accelerated by grinding minerals. It is not possible to include fat premixes.

There are many cheap forms of batch weighers available on the market. A very basic system can give you an accuracy of better than 0.25% and, when dealing with certain expensive ingredients, this is a sound investment. Many of these weighers incorporate micro technology.

Pelleting

Farm pelleting is not economically viable under 300 t/yr. There are two processes available: cold pelleting; steam (hot) pelleting.

Cold pelleting

Cold pelleting has gone out of fashion because it does not cook the ingredients and, therefore, there are nutritional constraints. Moreover, most cold pelleters have lower outputs than hot presses. It should be realised that the national compounders no longer use cold pelleters.

Steam pelleting

Hot pelleting requires steam at approximately 50 kg of steam per tonne per hour of output. It allows full flexibility of formulae, gelatinisation of starches, addition of molasses and restitution for some of the grinding loss by way of moisture up to about ½%.

Pelleting of either sort is an art which demands skill and the right equipment. Coolers and sieves are essential to both methods if a saleable and transportable product is necessary. Uncooled product will go mouldy quite quickly and will also crumble. Properly cooled pellets require 0.5 m^3/s of air per tonne. Consider the number of times users have complained to their compounders about dusty nuts, crumbly cake, etc!

Contamination

Keep down dust levels, since this is a hazard for both men and cattle and constitutes a fire risk. Cross-contamination really becomes a problem when you start to add drugs, growth promoters, etc, and there fore it is always recommended that medicants are added directly into the mixer.

Quality control

The one cardinal rule in home mixing is quality control. In practice, this means:

1. responsible, trained and intelligent staff;
2. accurate metering or weighing of raw materials;
3. regular laboratory analysis of ingredients (especially the variable ones);
4. sound feed formulations and nutritional advice;
5. care and maintenance of equipment.

Overall appraisal

Provided one is prepared to do the job properly, milling and mixing is said to offer considerable advantages, namely:

1. lower feed costs;
2. guaranteed ingredients — known contents of mix;
3. fresh food — usually eaten within hours of manufacture;
4. flexibility with formulating different diet specifications as required.

Some of these advantages, however, may not be as real as they might first appear.

Feed costs for a truly comparable diet may not always show the expected advantage; particularly on a rising market, the compounder may have bought cheaper, and in addition, has the ability to utilise a wider range of raw materials compared with the average home mix.

A knowledge of the raw materials incorporated in the ration may be of little value if there are no established quality control procedures. The compounder knows that his raw materials are up to specification. How many home mixers have such a procedure?

There may be a shorter gap between manufacture and feeding for home mixed feed, but the faster throughput of raw materials through a compound mill may mean that the feed ingredients themselves are fresher.

According to the Agricultural Development and Advisory Service figures, labour requirements range from 0.75 man hours per tonne for a small batch-mixing unit, down to 0.25 man hours per tonne for an automated plant, discharging mixed feed by auger to a holding bin, feeder trailer or tote bin. A medium-sized unit, mixing 10 tonnes a week should theoretically take about five man hours a week, but unnecessary "humping" of bags should be avoided.

Typical running costs are presented below.

For meal production per tonne:

Electricity	£1.00 — £1.50
Maintenance	£0.75 — £1.25
Processing loss	1% — 3%
Labour	⅓ — ¾ man hour

For pelleting per tonne, ADD:

Electricity	£1.50
Maintenance	£1.50

Conclusions

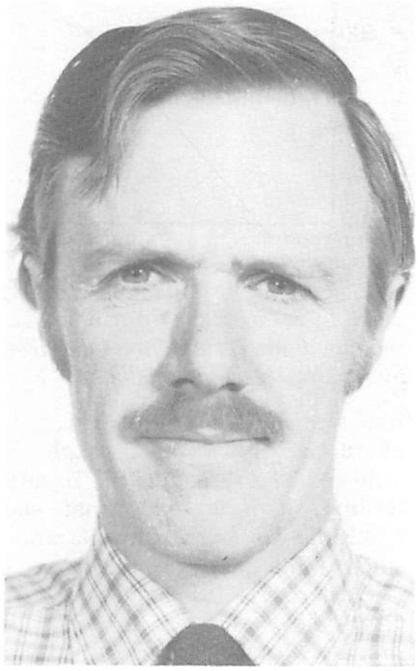
Investing in on-farm mixing is not like replacing a tractor. It should be tackled as a major expense, because it means learning a manufacturing skill plus acquiring a knack for buying raw materials. The built-up system is favoured, whereby the best machines of different makes are combined, plus possibly some secondhand plant from a closing-down mill sale. The complete milling and mixing plant should be planned, drawn and engineered by a company with experience of such on-farm plant. Seek advice from more than one company and pool their ideas before settling with one main contractor.

Concentrate feeding

M J B Turner

Abstract

Compound feeds are an essential part of the diet of the high yielding dairy cow. This paper discusses the requirements for concentrate dispensing and looks at how well these requirements are being met by available equipment. It covers both volumetric and gravimetric dispensers and both in-parlour and out-of-parlour situations. It concludes that the trend towards feeding the bulk of concentrate rations outside the parlour will continue. However, it forecasts a continuing role for simple in-parlour feeders delivering relatively small quantities of supplementary rations.



Introduction

Compound feeds or concentrates are an essential part of the diet of the high yielding dairy cow. The amount required to support a given production level will depend on the liveweight and the milk yield of the cow and on the intake and feeding value of the forage ration, usually silage. Increasing the intake of concentrates depresses the intake of silage and the art of the dairy farmer is to balance the cow's intake to achieve optimum production with minimal risk of digestive disorders.

Because the voluntary intake of silage increases with increasing dry matter content and digestibility and decreases with increasing ammonia -N (Stuart Jones, 1983), the farmer must always aim to make high quality silage so that it can contribute its full potential towards milk production and minimize the amount of expensive concentrate required.

The question for the agricultural engineer is how does the farmer wish to feed the concentrate, that is in what quantities, how often, where and how accurately.

The majority of farmers in the UK base their rationing philosophy on controlled feeding of concentrates and *ad-libitum* or 'to appetite' feeding of silage, although to judge the latter might prove difficult. With this philosophy, it is essential to dispense the concentrates to the individual cows with some precision and it is desirable to record the amount eaten. The difficulty is to decide what level of accuracy is required in dispensing because, inevitably, the higher the accuracy, the higher the cost of the equipment. If the bulk forage is very variable in quality, this will affect the intake and hence total energy input to the cow. In such circumstances, the value of highly accurate concentrate feeding may be lost unless the concentrates form a major part of the ration.

It is important to define more clearly what is meant by accuracy in this context. Accuracy is a measure of the closeness achieved to the desired target. In the present context, it comprises two distinct factors, 'precision' and 'bias', sometimes referred to as 'repeatability' and 'offset'. Occasionally, the bias or offset is referred to as accuracy; this should not be encouraged. A useful analogy is that of an archer aiming at a bull's eye. If he can group his arrows close together but some distance from the bull's eye, he is achieving high precision, ie good repeatability, but is showing bias in his shooting. If he scatters his arrows widely around the target but with a mean impact point in the bull's eye, then he is showing no bias but low precision or poor repeatability. If he groups his arrows on or very near the bull's eye he is achieving high precision and low bias.

In practical machines, high precision and low bias tend to be expensive to achieve. Concentrate dispensers are thus often a compromise between cost and performance. Wiktorsson and Knutsson (1977) showed that day to day variations of ±15% in the amount of concentrate fed to cows resulted in significantly lower milk production and extension of the calving interval. However, they did not state what level of day to day variation produced no significant difference. We must assume therefore that precision in concentrate feeding is worthwhile and that if the coefficient of variation (C of V) on the daily ration approaches ±5%, there may be problems. A good dispenser will have a coefficient of variation of less than ±2%, on a delivery of about 5 kg, this means if one measured the output a large number of times with a given feed compound, about two thirds of the measurements would lie within ±2% of the mean. The mean may well differ from the target but this difference, ie bias or offset, should be capable of being adjusted to zero or allowed for in the feed calculation.

In the following sections, various methods of dispensing concentrates will be considered with particular emphasis on how well they are likely to comply with the requirement for high precision and low bias.

Principles of dispensing concentrates

Methods of dispensing can be divided into two distinct groups, those based on volumetric principles and those based on gravimetric (weighing) principles.

(i) **Volumetric dispensing**

This group includes such devices as

Mike Turner is in the Farm Buildings Division of the National Institute of Agricultural Engineering and is the Subject specialist for livestock feeding and handling.

This paper was presented at the Scottish Branch Annual Conference entitled "Preparing feed for dairy and beef" and held at Dunblane Hydro Hotel on 15 February 1984.

augers, vibrators and other conveyors in which timing or counting of operations, eg rotations or vibrations, determines the amount dispensed. Also included are devices in which a fixed volume is filled and emptied. The factors which influences bias in volumetric devices are the physical characteristics of the feedstuff such as particle size, bulk density, moisture content, angle of repose, coefficient of friction and the cohesive nature of the material. Also influencing bias are mechanical factors such as the operating speed of the device and vibratory effects in the mechanism. A major alteration in any one of these often inter-related factors may alter the amount dispensed. It follows that the precision or repeatability of these devices is determined by the inherent variation in each of these factors. For example, if the bulk density is variable, then the weight delivered by a volumetric feeder will be equally variable. If the supply of material to the dispenser is variable because of bridging or 'rat-holing' in the supply hopper, then precision will suffer. In many practical cases, considerable degradation of compounded pelletted feeds occurs between the factory and the cow. Figure 1 illustrates how degradation affects bulk density and hence the weight delivered by a volumetric dispenser.

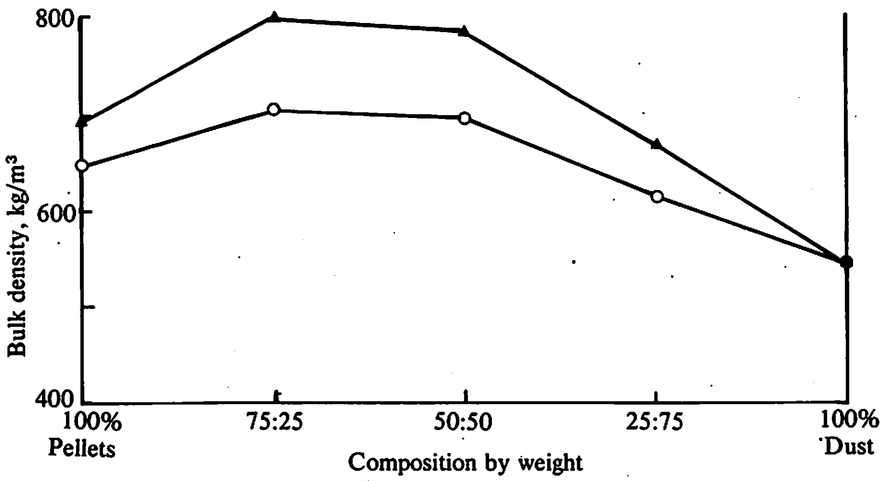


Fig 1 Effect of concentrate degradation on bulk density before (o) and after (▲) shaking down; results from laboratory trial – whole pellets, 8 mm diameter, mixed by hand with crushed pellets

(ii) Gravimetric dispensing

In the food industry, various methods are employed to ensure that the stated quantities are deposited in a container (Anon 1971). Often a rapid rough fill to slightly underweight is followed by an accurate weighing and a final topping-up from the required combination of smaller pre-weighed dispensers. An alternative is a fast rough fill followed by a slow final fill. In cattle feeding, it is unlikely that such precision will be worthwhile and a single filling stage is usually adopted.

Turner *et al* (1977) and Scholtysik (1980) have analysed in detail the processes occurring during the filling of a weighing hopper in a gravimetric feeder and it is worth considering the main conclusions of the former paper here.

In the ideal case, shown in fig 2a, the opening and closing of the feed gate on the supply hopper (or the starting and switch off of an auger, vibrator or conveyor) are infinitely quick; full flow is established or cut off immediately; the initial vertical velocity of the material is zero and the dropping height is constant. In such a case, the trip point is reached C seconds after opening the feed gate and the final amount in the hopper is the mass equivalent to the trip setting.

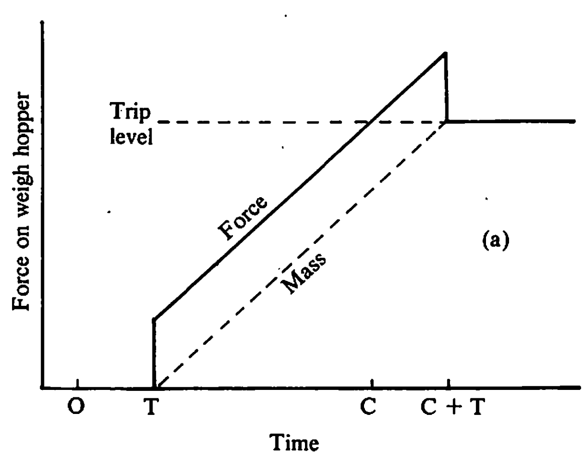
In the practical case, shown in fig 2b, the situation is far more complex and the final amount in the hopper is given to a good approximation by

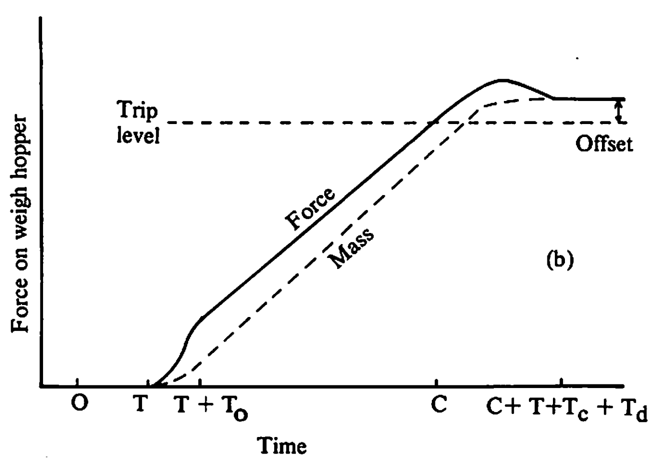
$$\text{Final mass} = F_c/g + R\,(T_c/2 - u/g + T_d) \quad (1)$$

where F_c = trip setting
g = acceleration due to gravity
T_o = time to establish full flow (fig 2b)
T_c = shut off time for feed gate
u = initial vertical velocity of material
T_d = time delay between detection of trip point and actuation of feed gate
R = rate of flow of material
T = time of flight (fig 2)

Thus, in any simple gravimetric feeder, the control unit must include an offset adjustment to allow for materials of different flow rates. Notice that the height of drop is not important provided that the total

Fig 2 Hypothetical graphs of downward force and mass in a weigh hopper as filling proceeds a) ideal case, b) pratical case





amount in flight is less than the lowest weight required.

In gravimetric feeders, the offset or bias obtained with different feedstuffs will be determined by the flow rate of the materials assuming the vertical velocity and shut off times are not affected. The precision or repeatability of dispensing for a given material will be determined primarily by the variability in the flow rate of the material. The actual values of bias and precision will depend on how large the last three terms in equation (1) are in relation to the first. Thus, with most types of gravimetric dispenser, the larger the size of each shot or delivery, the smaller should be the percentage error and variability. With the simpler mechanical types of gravimetric feeder used for dairy cattle, the ration is usually dispensed as a series of standard shots of about ½ kg.

There are two other methods of gravimetric weighing which are used in agriculture. Both are continuous weighing techniques. In one type, a weighing conveyor (Dawson *et al* 1976) is used to totalise the amount of grain passing over it. In the other, the impact force of grain hitting a plate (Hooper and Ambler 1979) is recorded and integrated over time to give a record of throughput. Neither is of much use in the feeding of small quantities of concentrated feeds to dairy cows, the devices being generally restricted to bulk grain handling operations.

Equipment available

In-parlour feeders

There are many different types of volumetric feeder which can be used for in-parlour feeding. Figure 3 shows examples of eight such devices all characterised by their simplicity and hence cheapness. Figure 3.1 shows one of the most common types, the auger feeder. The auger which may be tapered, stepped, centreless or of variable pitch is usually driven by a low voltage dc motor, however pneumatic and vacuum operated versions exist. Rationing is done either by controlling the time the motor runs or counting the revolutions of the auger.

The flat plate dispenser (fig 3.4) relies on the material being retained in the feeder by virtue of its natural angle of repose. The feed is dispensed by lifting the hinged plate situated above the fixed base plate. To alter the shot size, the travel of the hinged plate and the angle of the base plate can be adjusted. Actuation is usually by a vacuum operated ram.

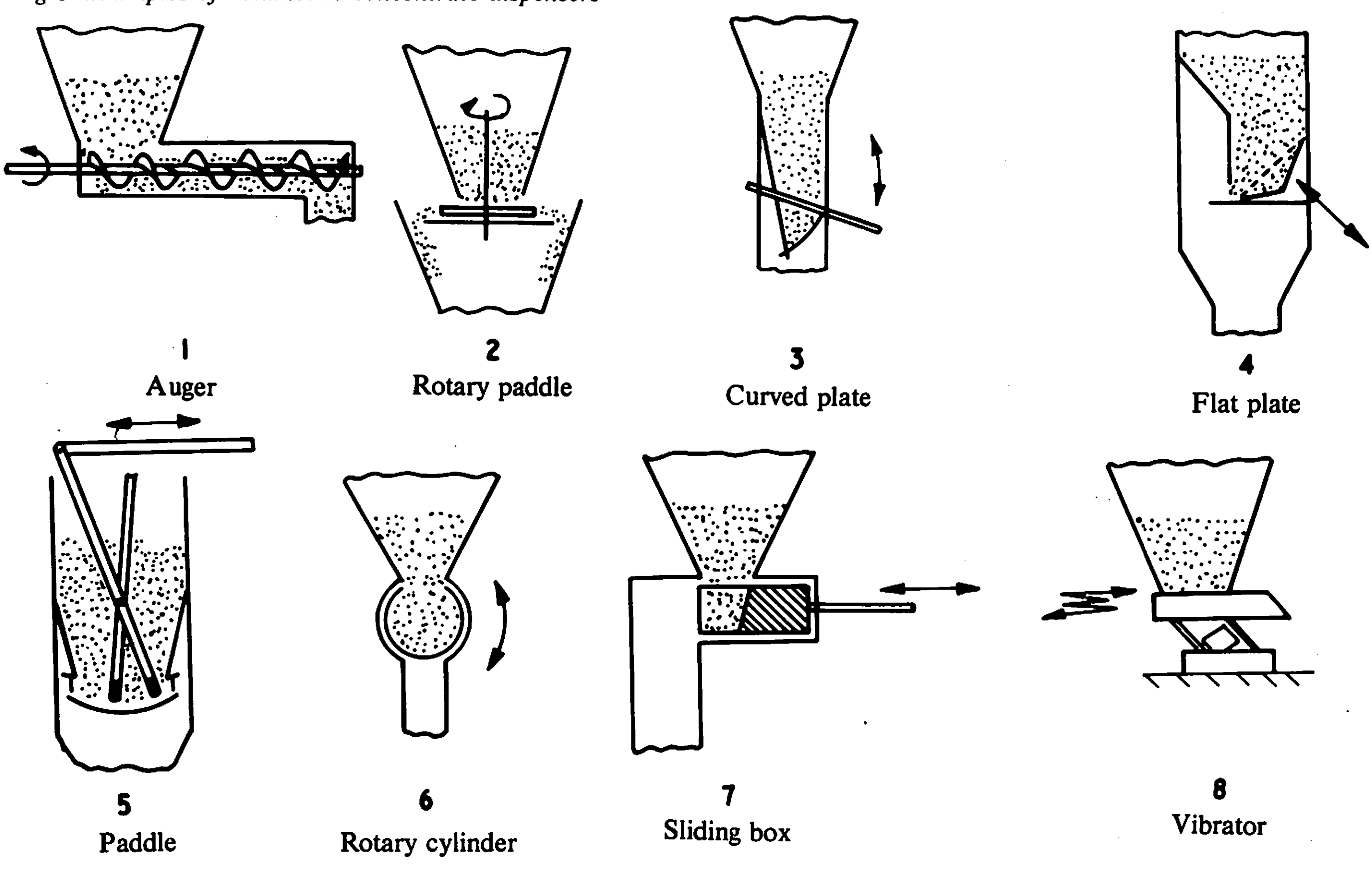
The dispenser using a split cylinder rotating about a horizontal axis is shown in fig 3.6. The cylinder is filled by flow under gravity and then rotated 180° to release the food. The volume of the cylinder can be altered to control the shot size.

In the sliding box feeder (fig 3.7), once again a volume is filled by flow under gravity. The box is then slid sideways away from its base, thus allowing the food to drop down the outlet chute. Adjustment of shot size is by alteration of the volume of the box.

The vibrator feeder (fig 3.8) comprises a short trough mounted on springs beneath a hopper. The trough is electromagnetically vibrated for the required time. The rate of delivery can be controlled by altering the current supplied to the coil of the electromagnet.

The other dispensers are less common: in fig 3.5 a paddle pushes the food over the edge of a curved plate, in fig 3.2 a rotating paddle pushes the food over the edge of a flat fixed disc and in fig 3.3 a curved plate releases a trapped volume of food each time it is lifted. Many papers have been published describing particular designs of concentrate dispenser and are too numerous to list here, however one by Wendling

Fig 3 Examples of volumetric concentrate dispensers



(1979) gives details of several other types of volumetric feed dispenser.

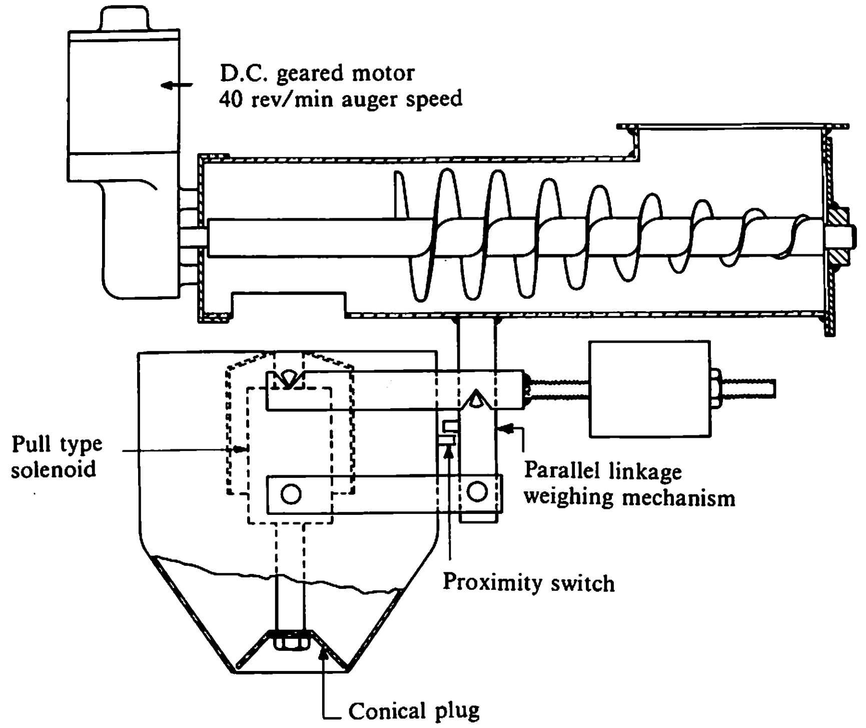
Three gravimetric feeders were developed at the National Institute of Agricultural Engineering, two for fixed parlours, and one for rotary parlours. The first two (fig 4.1 and 4.2) used tapered or stepped augers to fill a weighing bucket supported either by a mechanical lever arrangement (Dawson and Turner 1976) or a crossed flexure pivot (Crowther and Street 1977). The trip level was sensed by a proximity switch in the first case and an ordinary microswitch in the second case.

The gravimetric feeder for the rotary parlour (Turner *et al* 1977) in fig 4.3 used flow under gravity over a specially designed ledge on the feedgate to fill the weigh hopper which was mounted on a cantilever load sensing beam fitted with strain gauges.

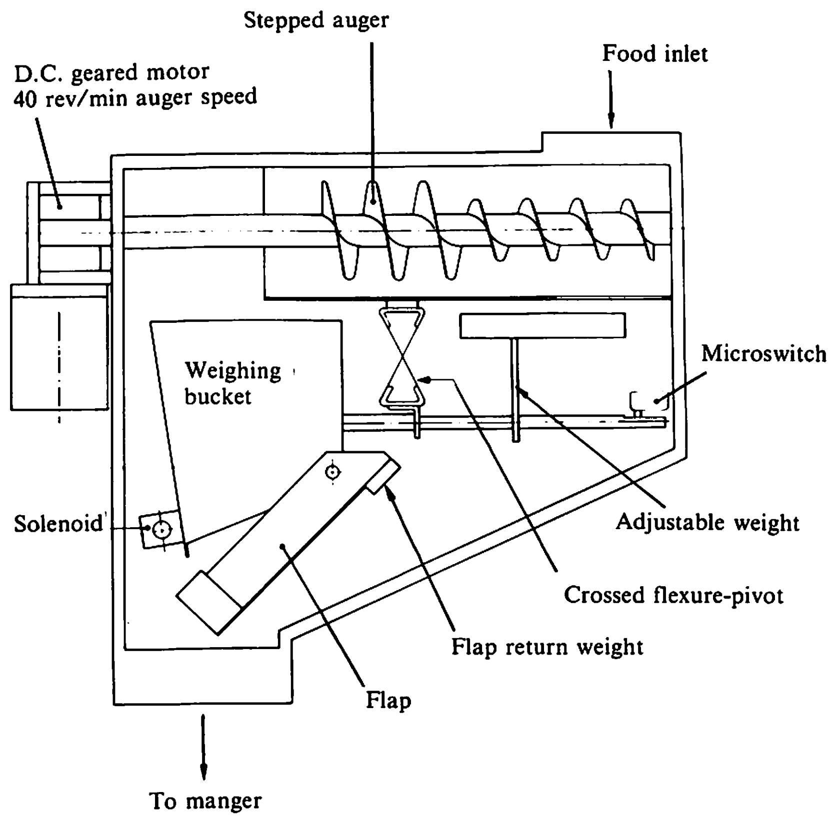
Commercial versions of these feeders are now available, that for the rotary parlour is virtually identical to the original NIAE design. The version for fixed parlours uses a vacuum operated vibrating mechanism similar to that shown in fig 3.4 to fill a weighing tray. When the appropriate shot weight is reached, the tray is rapidly tipped and reset ready to receive the next shot.

It is difficult to obtain realistic figures for accuracy (repeatability and bias) in practice primarily because of the differing conditions from day to day in the parlour and storage hopper. Often with volumetric feeders, one can get good figures one day for bias and repeatability and next day find the bias has changed appreciably. Measurements by Dawson (1980) on several dispensers taken on 70 days during a period of four months are fairly representative of the long term repeatability. The pellets used throughout the period were of the same brand with an approximate bulk density of 690 kg/m^3 and a diameter of 8 mm. A summary of his results plus some comparable ones from other sources are shown in table 1. The flexible pivot gravimetric feeder and flat plate feeders were installed in a parlour. The material dispensed by these on each occasion was collected and, after being weighed, was immediately used to determine the performance of a timed auger and a vibrator feeder set up in the laboratory. The results for the rotary parlour feeder and the tipping tray were obtained from other farms.

The results in table 2 show the repeatability of measurements taken on a given day for various types of feeder. Notice how the volumetric types markedly improve in repeatability when there is little opportunity for the characteristics of the concentrate to alter. The gravimetric feeders generally show little change in repeatability as might be expected.

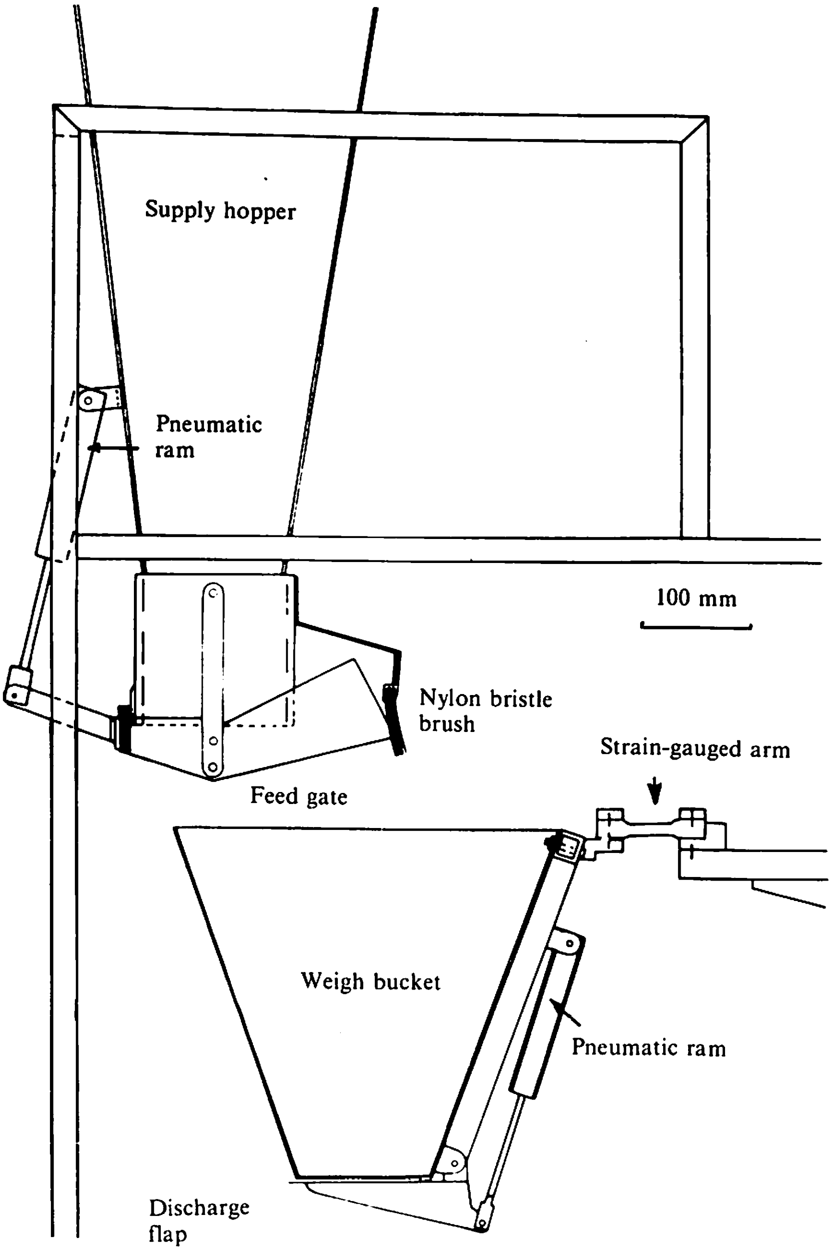


1



2

Fig 4 Basic principles of NIAE gravimetric feeders: (1) early lever balance, (2) flexible pivot, (3) rotary parlour version



3

Wendling (1979) has published figures indicating a marked variation in the performance of volumetric feeders as the moisture content of feedstuffs alters.

Pirkelmann (1983) has looked at the accuracy of dispensing of both out-of-parlour feeders and scale-beam feeders in tie-stalls. In the former case, he concludes that rations as low as 250-300 g can be dispensed to within about ±5%. In the case of the scale-beam feeders, the accuracy improved with the weight delivered, the coefficient of variation being about 5% at between 1.2 and 1.5 kg.

Larsson (1978) has looked at how the segregation and disintegration of feeds in various types of conveying system affects the precision of dispensing. He recommends the use of augers for conveying and gravimetric dispensers for delivery. Mixes of rolled grain and pellets were found to be highly prone to segregation, resulting in different nutrient contents being delivered along a row of feeders.

With all volumetric feed dispensers, it is important to check their calibration at regular intervals, particularly when the quality of the concentrate alters, eg a new brand, a different diameter pellet, a very dirty sample or a waxy sample. The bulk holding facilities for concentrates should also be kept free from bridging and old material not allowed to accumulate and rot. Generally, the frequent movement of material in the small hoppers above each feeder will help to prevent blockage unless foreign objects, such as dead birds, rats or pieces of wood, get entrained. With gravimetric feeders and the 'volume filling' type of dispenser, it is important to also check whether feed is sticking to and building up in the weighing hopper or container. This can happen, particularly in cold weather, with metal hoppers when condensation occurs. Only the rotary parlour feeder with its electronic weighing facility can take account of food build up by automatically re-zeroing the hopper. All the others must be kept free of build up, otherwise a considerable bias may be introduced in the output.

A mechanically tripped gravimetric feeder needs a weight sensing device and sometimes this can have a dual role in that it can be used to determine whether the feeder is working properly. For example, if the sensor is not actuated within a given period after the filling of the weigh hopper starts, then something is wrong. The bulk hopper may be bridging or the release flap jammed open or one of the other mechanisms is failing to operate.

Table 1 Long term repeatability of in-parlour feeders (months) (based on nominal delivery of 10 lb or 5 kg of pellets)

Type of feeder	*Coefficient of variation, %*	*Source*
Volumetric		
Timed auger	4.7	Dawson (1980)
Vibrator	5.0	Dawson (1980)
Flat plate	6.4	Dawson (1980)
Gravimetric		
Lever balance	2.4 - 2.8	Dawson (1977)
Flexible pivot	1.9	Dawson (1980)
Rotary parlour type	0.8	Dawson (1980)
Tipping tray	1.1	Author

Out-of-parlour feeders

The dispensing mechanisms used in these are often identical to those used in in-parlour feeders. A useful

Table 2 Short term repeatability of in-parlour feeders (same day) (based on nominal delivery of 10 lb or 5 kg of pellets)

Type of feeder	*Coefficient of variation, %*	*Source*
Volumetric		
Timed auger	1.7	Dawson & Turner (1976)
Vibrator	0.8 – 1.8	Barlow (1977)
Flat plate	2.4 – 4.3	Author
Gravimetric		
Lever balance	1.1	Dawson & Turner (1976)
Flexible pivot	0.9	Dawson (1977)
Rotary parlour type	0.6	Author
Tipping tray	0.6	Author

summary of the equipment available in the UK is presented by Marshall (1983). Most common are the auger type; variations include a twin auger version, a feeder with two hoppers and two augers for supplying different qualities of concentrates, and an auger with a cupped end to avoid dribble. The major difference, however, lies in the quantity of concentrate supplied in each delivery. With an out-of-parlour feeder, it is important that a cow displaced by a bullying cow should not leave any appreciable amount uneaten. Hence the policy is to supply concentrates at a rate slightly lower than that at which the cow can eat. Typical rates are in the region of 250–500 g a minute. This may be supplied as a dribble or as a number of discrete shots per minute. A recent survey of out-of-parlour feed dispensers by ADAS (1983) suggests that a dispenser can deliver about 250 kg per day and the number of cows/dispenser can be calculated by dividing this figure by the average daily allocation in kg/cow. The survey also looked at the bias and repeatability of dispensing on thirty two farms and included examples of eight different makes. A visit was made to each farm at approximately monthly intervals during five consecutive months of winter feeding. At each visit, the same feed dispenser was programmed to deliver twelve consecutive 1 kg portions. If necessary, recalibration was done after the visit. It was concluded that any make could operate with a bias of less than ±5% and with a repeatability (precision) of less than ±5% coefficient of variation. However, it was recommended that regular calibration was essential and must be done whenever a fresh delivery of food reaches the dispensers. This recommendation is not surprising as all but one of the available makes use volumetric dispensing techniques. In several types, the calibration figure can be entered into the control console which then takes the appropriate corrective measures to determine the required number of shots for each cow. This avoids the need for mechanical adjustment of the dispenser.

The control consoles vary in detail but basically all record the identity of the cow at the feeder, deliver the appropriate amount of concentrate for the feeding period, keep records of the total daily delivery to each cow and print out lists of allocations and amounts delivered and indicate cows needing attention.

Because the cows are not forced to visit the feeder as they are with in-parlour feeders, it is important to site the out-of-parlour feeders in areas where access is unhindered and cannot be blocked by antagonistic cows. Also it may be necessary to train some cows to use the feeders, although some users claim that training has proved unnecessary in their situation.

Many studies have been conducted on the use of out-of-parlour feeders and related cow behaviour (Rix 1978, Smits 1978, Hyde *et al* 1976, Pojtner 1983) and this subject will not be pursued further here. The problem of siting out-of-parlour feeders for both summer and winter use has been considered (Little, 1982) and special arrangements usually have to be made to ensure regular intake by cows at grass. Out-of-parlour feeders need regular maintenance, perhaps more so than in parlour feeders because they will be serving perhaps three times as many cows/day. Generally, the same sort of problems encountered with in-parlour feeders might be expected and will need dealing with from time to time. Regular calibration cannot be over emphasised, otherwise the figures on the print-out for rations dispensed will be of reduced value for management.

Calibration of feeders

It is worth considering briefly how many readings are necessary during a calibration check. Table 3 shows the approximate number required to establish whether the mean amount dispensed has moved by more than b% from its previous value, ie to establish whether re-calibration is necessary.

Table 3 Number of readings to establish with 99.8% confidence that the mean has altered by more than b% from its previous value

Coefficient of variation, %	*Number of readings for % change of* 1	2	3	4	5
1	10	3	2	1	1
2	39	10	5	3	2
3	86	22	10	6	4
4	153	39	17	10	7
5	239	60	27	15	10

From the table it can be seen that if in practice only 10 checks can be performed on a feeder then the percentage bias could be as high as the coefficient of variation.

For example, for a feeder with a coefficient of variation of ±5% on a delivery of 5 kg, at least 10 checks at 5 kg would have to be made to establish whether the mean value had a bias of more than 250 g. On the other hand, if the coefficient of variation was ±2%, only two readings would be sufficient.

For calibration purposes, the coefficient of variation values such as those in table 2 for short term repeatability are the relevant ones.

Other methods of concentrate feeding

Whilst out-of-parlour feed dispensers have become very popular in recent years following the development of cow identification devices, it must be remembered that other methods of feeding concentrates outside the dairy parlour are still widely practised.

These range from totally manual methods, such as dribbling food along the mangers from a sack, to complex conveyor feeding systems. The manual methods can be very accurate to the herd as a whole and, indeed, if the cows are held in yokes or cowtraps, then individual cows can be fed accurately using a weigh pan and scale on a trolley carrying the sacks or a hopper of food. Slightly less accurate are the mobile concentrate dispensers which use an auger to discharge into the manger. A mobile gravimetric feeder designed jointly between the National Institute of Agricultural Engineering and the National Institute for Research in Dairying (Crowther and Turner 1983) is now on trial at Arborfield. This is basically a vehicle-mounted feeder of the type developed for the rotary parlour.

In Scandinavia, it is fairly common to find gravimetric concentrate feeders fitted above the individual stalls where each cow spends the winter. These feeders are usually of the counterbalance lever type and are adjusted by hand as necessary to alter the ration. Accuracy improves with the weight dispensed (Pirkelmann 1983).

In loose housing situations in the UK and USA, cows are often divided into groups requiring different rations. In such cases, it is possible to mix a large percentage of the required concentrate ration with the bulk forage either using a mixer wagon or one of a variety of conveyor feeding methods (Turner 1980). In such circumstances, the farmer may decide not to feed concentrates on an individual basis in the parlour but rather to use the in-parlour feeders to deliver a small standard ration perhaps containing minerals or medicinal additives thus ensuring that each cow in the milking herd has an opportunity for such intake.

Conclusions

It is difficult to forecast how concentrate feeding will develop further in the UK. I think we will see less emphasis on in-parlour feeding and the bulk of the concentrate fed outside the parlour. Part will probably be mixed with the forage to provide a basic ration and the rest fed on an individual basis. In-parlour feeders will probably be simplified to deliver only small quantities of supplementary mineralised feeds. Opportunity feeds such as sugar beet pulp, brewers grains, surplus carrots etc will continue to be mixed with the bulk forage in mixer wagons or in conveyor feeding systems. There is little prospect at the moment of producing controlled feeders for brewers grains or sugar beet pulp, although some work has been done on individual control of silage intake (Horton 1983, Ipema *et al* 1983).

Out-of-parlour feed dispensers offer many advantages for management; for example closer monitoring and control of performance, saving of labour and convenience of feeding time. Also in early lactation, they can be useful in allowing frequent feeding of small meals, thus reducing the risk of digestive disorders whilst trying to maximise dry matter intake. Also they allow the more timid cow or young heifer a better chance of obtaining its correct rations of concentrates than in the free-for-all at the communal manger. However, in-parlour feed dispensers do enable some food to be given during an otherwise wasted 2–4 hours a day while the cows are waiting and being milked. They allow regular presentation of concentrate, though not guaranteeing intake for cows at grass and a more reliable means of mineral supplementation for grazing cows. Unfortunately, they create dust and complication in the milking parlour and the future may see either their complete removal or a simpler cleaner system installed for in-parlour feeding of a base level of concentrate. For example, if all the feeders are required to dispense the same small amount in a parlour, it is really nonsense to have one fairly expensive feeder per stall. One or two more expensive feeders set just outside the parlour with a simple means of distribution to each stall may be a preferable alternative.

References

ADAS (1983). Out-of-parlour feed dispensers. Publication DHMP/24. Min Agric Fish Food.

Anon (1971). Automation in the food industry *Process Control,* June, pp 9–15.

Barlow P F (1977). Private communication.

Crowther J S W, Street M J (1977). Simple control circuits for use with NIAE gravimetric feed dispensers for concentrates in static milking parlours. Div Note LC/807/04018. Natn Inst agric Engng, Silsoe. (unpubl).

Crowther J S W, Turner M J B (1983). A control circuit for a mobile concentrate dispenser. Div Note DN 1164. Natn Inst agric Engng, Silsoe. (unpubl).

Dawson J R, Hooper A W, Ambler B (1976). A continuous weigher for agricultural use. *J agric Engng Res,* **21,** 389–397.

Dawson J R, Turner M J B (1976). A gravimetric feed dispenser for the dairy parlour. *J agric Engng Res,* **21,** 439–441.

Dawson J R (1977). Private communication.

Dawson J R (1980). Equipment for feeding concentrates in and out of the parlour. Br Soc Anim Prod Occl Publ No. 2, 155–169.

Hooper A W, Ambler B (1979). A combine harvester discharge meter. *J agric Engng Res,* **24,** 1–10.

Horton C (1983). Selective access managers. Proc Symp on Automation in Dairying. Wageningen. April. pp 291–295.

Hyde G M, Olver E F, Harshbarger K E, Puckett H B, Spahr S L (1976). Factors affecting dispensing rate of an automatic dairy concentrate feeder. *Trans Am Soc agric Engrs,* **19,** 792–795.

Ipema A H, Rossing W, Cornelissen J G, Janssen T (1983). A system for the individual dispensing of forage. Proc Symp on Automation in Dairying. Wageningen. April. pp 43–59.

Larsson K (1978). Transport and metering concentrates in mechanised feeding systems. Publ No. 374 Meddelande, Jordbrukstekniska Institute, Uppsala, Sweden.

Little W (1982). Behaviour of cattle using an automated feeding system. Paper at Summer Mtg of Soc for Vet Ethology. Reading. July.

Marshall I (1983). Out-of-parlour feeders. *Power Farming,* June, pp 16–19.

Pirkelmann H (1983). Technical and biological factors for automated feeding of dairy cows. Proc Symp on Automation in Dairying. Wageningen. April. pp 61–67.

Pojtner M (1983). Adaptation, compound feed intake and milk production of dairy cows fed by means of Alfa-feed automatic feeders. Proc Symp on Automation in Dairying. Wageningen. April. pp 33–42.

Rix J (1978). Transponder feeding in practical use. *Landtechnik,* **33,** 404–407.

Scholtysik B J (1980). Effect of the mode of mass flow on the metering efficiency of gravimetric feed metering devices. *Grundlagen der Landtechnik,* **30,** 61–68.

Smits A C (1978). Automatic

concentrate feeding and the behaviour of dairy cattle. *Landbouwmechanisatie*, **29**, 1087–1090.

Stuart Jones M G (1983). The diary cows requirements for compound feeds. NAC Dairy Conf. Stoneleigh. Nov.

Turner M J B, Barlow P F, Arnall B (1977). A gravimetric feeder for use in rotary milking parlours. *J agric Engng Res*, **22**, 65–77.

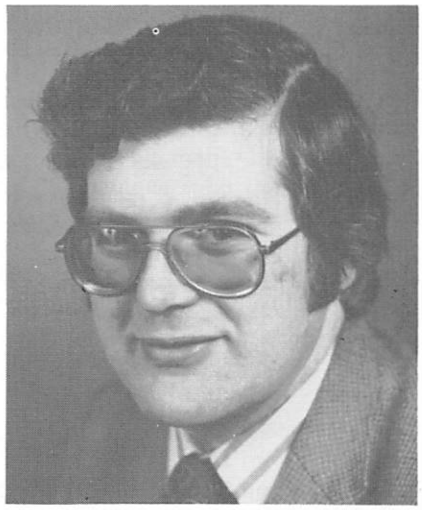
Turner M J B (1980). Conveyor feeding of cattle. Report No. 34. Natn Inst agric Engng, Silsoe.

Wendling F (1979). Volumen oder Gewichtsdosierung fur die Kraftfutterfutterung. *Landtechnik*, **2**, 69–71.

Wiktorsson H, Knutsson P G (1977). Effects on milk production of controlled variation in concentrate feeding. *Swed J Agr Res*, **7**, 159–162.

The economics of home feed processing

J McN Fisken



Summary

AS the size of livestock enterprises on British farms have increased, there has also been a significant increase in the volume of feed processed on the farm. The capital currently involved in installing a milling and mixing plant, especially the high output units, makes it imperative that the costs and benefits are carefully assessed from two aspects:

1 the rate of return achieved by the investment;
2 the resources available to finance and run the plant.

Under many circumstances, especially when there is a new livestock enterprise or limited capital available, contract milling and mixing may provide an alternative to home mixing, while minimising demands on labour and management. In other situations, the discount and credit facilities offered by manufacturers may result in cheaper rations than home milling and mixing. A farmer, currently home milling and mixing or about to install a plant, should pay particular attention to the quality of rations produced, ensure effective purchasing of raw materials and maximum utilisation of production capacity.

It is important that each farmer ascertains the effect on the financial status of his business where installation of a milling and mixing plant is being considered. In particular, where capital is borrowed to finance the investment, the farmer must consider the effect this will have on financing the other parts of the business. A feasibility study, especially for those farmers with high levels of borrowing, is deemed essential.

Introduction

In the last 30 years, the rapid increase in the size of poultry, pig and cattle units has dramatically increased the volume of feed processed on the farm. As a result, the capital invested in such installations has risen rapidly. This paper will attempt to highlight the important economic factors associated with home-milling and mixing. In reviewing these factors it is important to consider the alternatives of purchasing from compounders, on-farm contract-mixing and feed processing by farmer co-operatives.

Investment considerations

In past years many farmers invested in longer term plant and building projects, safe in the knowledge that gradually increasing inflation would reduce the real cost of capital investment. Recently, however, there has been a significant fall in that rate of return and the imprudent have invested too much, too quickly, in long term, low earning assets. It is, however, difficult to generalise on the economic benefits of home milling and mixing, as so much depends on the individual circumstances of the farm and the farmer.

Nevertheless, the question most farmers ask, or should ask, before embarking on home milling and mixing is: "Will it pay?". Evidence from costing schemes run by national organisations such as the Meat and Livestock Commission and Milk Boards suggest that home mixed rations are cheaper than purchased compounds, even after milling and mixing charges are included. The discounts currently being offered by manufacturers to farmers purchasing large annual quantities may, however, make the installation of a milling and mixing plant quite unattractive. One example is the case of a farmer who has recently installed a sophisticated batch processing system capable of producing over 100 tonnes per week. The equipment is unused at present as he can purchase compounds for less than he can produce his own rations. This farmer feels, however, that the balance may shift in favour of home processing at some point in the future.

The capital requirements of a milling and mixing unit are such that there is a fundamental need to assess the costs and benefits carefully. Feed costs swallow a large proportion of gross output on all livestock farms, eg approximately 35% for dairy cattle, approximately 25% for winter finishing of beef cattle, and up to 80% on pig and poultry units. It is, therefore, hardly surprising that farmers attempt to minimise feed costs per tonne. The expectation of the home mixer is that processing costs plus ingredient costs will be less than the compound price by a margin which will be a profit to the business.

Before assessing any investment it is important to distinguish two separate aspects of that investment, namely:-

worthwhileness — the measure of extra profitability or return on capital which the investment will generate, and

feasibility — the measure of the adequacy of cash resources to meet the actual costs incurred by the investment.

Where a milling and mixing unit is being installed, the farmer or his adviser must:-

(a) ascertain whether rations can be produced at a lower cost per tonne than, say, purchasing or employing an on-farm

---

Jim Fisken is a Specialist Advisor in the Farm Business Management Unit at the East of Scotland College of Agriculture, South Oswald Rd, Edinburgh.

This paper was presented at the Scottish Branch Annual Conference entitled "Preparing feed for dairy and beef" and held at Dunblane Hydro Hotel on 15 February 1984.

contractor, the potential savings being related to the total additional capital investment to reveal whether the extra profitability or return on capital is adequate;

(b) examine whether he has the resources to meet the capital cost of the installation and the working capital required to run it.

One could envisage the situation where the returns from installing the plant could prove attractive, although the cash is unavailable to finance the project. This is the reason why it is difficult to generalise on the subject and the circumstances of each farm and farmer must be examined individually.

Systems appraisal

Each method of procuring feedstuffs, ie home milling and mixing, purchasing, on-farm contract mixing or co-operation, can claim both economic and non-economic advantages.

Home milling and mixing

1 Home milling and mixing does not have the cost of sales and administration, transport and distribution costs or profit that a compounder requires. Recently, a large compounder attributed 80% of the cost of a compound to raw materials and 20% to the afore-mentioned items.
2 The exact ingredients of the ration are known.
3 A degree of control can be exercised/maintained over feed costs and meeting nutritional requirements.
4 Fresh rations, minerals and growth promoters are always available.
5 Milling and mixing may be fitted into the existing grain handling and storage system.

Purchasing compounds

1 Capital expenditure is reduced.
2 Analysis is guaranteed but there is no ingredient specification. There is much discussion at present within the agricultural industry on this point.
3 Bulk delivery, discount and credit facilities are usually available.
4 Compounder may have better knowledge of the ingredients market and, perhaps, may purchase more advantageously than home mixers through the use of forward contracts and the futures market.
5 Labour requirment is low.

On-farm contract mixing

1 Savings are claimed through eliminating the fixed overheads common to conventional ration production, eg sales and manufacturing overheads. Charges for such services will vary, however, depending on the frequency and tonnages mixed.
2 Many of the supposed advantages of home mixing are also available under this method, eg fresh rations. On-farm contract mixers also claim that rations of more consistent quality and assured nutritional value are possible than with traditional home mixed rations.
3 Existing grain handling and storage systems can be utilised.
4 Labour, capital commitments and delivery delays are eliminated.

Co-operation

1 Individual farmer's "own" part of the feedmill. Capital requirements are supposedly reduced, compared to a home mill and mix plant.
2 There are opportunities for a lower labour requirement, no sales staff and potentially higher output over which to spread labour, interest and depreciation charges compared with home milling and mixing.
3 It is likely that particular attention will be paid to procurement of raw materials and quality control in the production of rations. This may produce improved performance and lower ration costs compared to home milling and mixing.

This type of feed processing appears to have been most successful where a group of farmers are looking for broadly similar rations, eg a group of bacon or pork producers.

Of the economic advantages mentioned for each method, it is perhaps worth mentioning the claim of discounts offered by compounders. The manufacturing cost of feed processing is greatly influenced by the efficiency in purchasing raw materials and economies of scale. This cost largely determines the level of profits achieved by feed compounders. The prices charged to farmers are generally geared to the producer whose production costs are the highest. This explains why some companies can afford discounts and special deals, whilst others cannot.

Over the past five years, the face of the compound feed industry has changed radically. It is likely that, in the foreseeable future, two large companies will be providing approximately 40 per cent of the total quantity of feed purchased by farmers. It remains to be seen whether the reduction in competition will curtail the level of discounts available to farmers.

Important factors in home milling and mixing

The actual installation of the equipment is only one aspect of the decision-making for a farmer who is considering home milling and mixing on his farm. The second aspect is the purchasing of raw materials where required, the formulating the ration. In some respects, these are the most difficult aspects of home milling and mixing for most farmers.

Quality control

A cardinal rule for home milling and mixing is *quality control* in the production of rations. This effectively means having responsible, trained and intelligent staff, accurate metering or weighing of raw materials, regular laboratory analysis of ingredients (especially the variable ones), sound feed formulation and nutritional advice and care and maintenance of equipment.

In financial terms, there is little point in saving £20 per tonne on feed costs if performance is depressed by £25 per tonne fed. In situations where the margin of savings from home milling and mixing is small in comparison to purchasing or on-farm mixing, a small reduction in feed conversion efficiency could alter the balance between home mixing and the alternatives.

Purchasing

Apart from ration formulation, the other area where difficulty may be experienced, especially where precise and complicated rations are required for dairy cows, pigs and poultry, is in buying raw materials. Enthusiasm is required to keep in touch with market trends and prices. The farmer must:-

1 have regular contact with four or five merchants, rather than buying from one source.

2 spend time whether on the telephone or at market, checking prices and getting quotes.

Utilisation of capacity

Whilst it is difficult to generalise about costs, the following example reveals the effect of throughput in relation to capital cost on the overall cost per tonne processed, regardless of circumstances.

Table 1 Capital cost of a small mill and mix unit with a throughput of 100 t/annum

Equipment	*Gross cost, £*
3.7kW mill 10.25 t/h and 1t batch mixer	3200
Conveyor	700
Installation and wiring	1000
Total	4900

Table 2 Cost per tonne processed

	Processing charge, £/t 50 t/yr	*Processing charge, £/t* 100 t/yr
Depreciation (7-year write-off)	14.00	7.00
Maintenance and repairs	4.90	2.83
Electricity	1.00	1.00
Grinding loss (2% of 900 kg at £115/t)	2.07	2.07
Labour (½ man-hour)	1.60	1.60
Total	23.57	14.50

There are obviously potential cost reductions where, for example, the conveyor equipment is already available in an existing grain storage system on an arable farm. Cost reductions may also occur where equipment is purchased second-hand, or where the equipment is written-off, although still in working order. In the latter case, the repair and maintenance charges incurred may increase. If the equipment is properly maintained, there would be little increase in the grinding loss over the years, the moisture content of the grain being more important. In practice, although the equipment is written off over seven years in the example, there are many units much older than this which are still in good working order. Also, the interest on capital invested in equipment has been excluded, this can be taken into account when return on capital is determined.

The example illustrates the importance of fully utilising capacity and becomes more important as the capital costs associated with larger sophisticated units, escalate. With high output installations, an extra man may be required and the grinding loss may range from one to three per cent. The interest involved in holding raw materials must also be considered. Some farmers are satisfied with holding only one month's stock of raw materials while others prefer to hold two to three month's stock. Any savings from home-processing must also cover the holding cost for there raw materials.

Ration cost comparison

Having calculated the running costs of the proposed plant it is then possible to compare the cost of home mixed rations with purchased compounds or on-farm contract mixed rations of similar nutritional composition. The cost of the ingredients should be similar in the latter if the farmer is supplying the raw materials. Any ingredient supplied by the contractor must be accounted for in the calculations.

Table 3 shows the cost of ingredients in beef finishing rations for a silage, hay or straw-based diets. The barley in these rations is assumed to be home-grown and costed at market value for the month of December 1983.

Table 3 Cost of ingredients for home/contract-mixed beef finishing ration

	Ingredient cost, £		
	With silage	*With hay*	*With straw*
Barley (£115/tonne)	113	99	99
Protein concentrate (£160/tonne)	–	22	–
Soya bean meal (£211/tonne)	–	–	25
Mineral/vitamin mix (£300/tonne)	6	–	6
Ingredient cost/tonne	119	121	130

Table 4 Total cost per tonne of home/contract-mixed beef finishing ration

	Total ration cost, £/t		
	With silage	*With hay*	*With straw*
Home mixed	134	136	145
On-farm contract mixed	135	137	146
Purchased	150	150	150

Table 4 shows the total cost per tonne of home mixed and contract mixed beef finishing rations compared to a purchased beef finishing nut of similar nutritional composition. Ingredient costs are taken from table 3. The processing costs for the home mill and mixed rations are based on the figures in table 2, rounded to the nearest £, assuming 100 tonnes per annum are processed. The on-farm contract charge in this example is £16 per tonne. Where larger annual quantities are being processed, the charge is normally about £12 per tonne for a 10-tonne mix.

The rate of return on the installation of a home milling and mixing plant can be assessed by comparing the potential savings in feed costs with the additional capital invested. Assuming 100 tonnes per annum are processed, the rate of return in this example on a capital investment of £4900, varies from 10% where a straw-based ration is fed, to 33% for a silage-based ration.

The rate of return achieved must be assessed in the light of current interest rates and the alternative investment opportunities. One should remember that this return must cover the interest on capital invested in both equipment and raw materials. For example, an interest charge of approximately £243 will be incurred in holding 100 tonnes of barley for two months when interest rates are 12% per annum and the current market price of barley is £115 per tonne.

Farmers, even those presently involved in home milling and mixing, can use this simple method to appraise their concentrate feeding system. When reaching the final decision on whether to start or continue with a home milling and mixing system, the farmer will, in addition to calculating the potential cost reductions, also have to evaluate the advantages claimed for the alternative methods of feed processing. In some circumstances, where there is a new livestock enterprise or limited capital is available, contract milling and mixing may provide a worthwhile alternative to home milling and mixing while minimising demands on labour and management. Alternatively, the discounts offered by compounders allied to the minimum capital expenditure required, may influence the final decision. Whatever the circumstances, each individual farmer should assess the costs and benefits carefully.

From an economic point of view the most important benefit to arise from treating straw with ammonia is the potential land saving. Stated simply, the land previously used to grow hay or silage can now be used to grow barley or some other cash crop. The result will probably be more expensive straw-based rations compared to silage or hay-based rations, but this will tend to be more than offset by the increased farm output from the sale of the cash crop.

A note of caution, however: farmers should consider, not only the potential increase in output from alternative enterprises, but also the effect upon the fixed costs and the capital requirements of the business. Any change, other than a very small increase in the cropping area, will increase output but may also require extra machinery, drying and storage facilities or labour, in which case the fixed costs and capital requirements of the business will also increase. It would appear that, at present costs and returns, there is a place for the technique as part of an integrated land use policy, but it is important that each farmer carries out a detailed analysis to ensure there is an improvement in profitability.

Check list

To summarise, a farmer must examine the following aspects before embarking on home-milling and mixing.

1 Is adequate labour available?
2 Do the existing buildings allow a mill and mix plant to be installed?
3 Does the capacity exist to store raw materials?
4 What is the annual tonnage of feed required?
5 Does the farmer purchase new or second-hand equipment?
6 What amount of capital can the farmer afford? The farmer will obviously be interested in the net capital cost, ie after capital grant.
7 Is the capital expenditure justified or could it be better employed elsewhere?
8 Who will undertake ration formulation?
9 Will sufficient time and expertise be available to ensure that raw materials are purchased at the most advantageous prices?

A feasibility study incorporating these points and also taking account of the capital allowances available on plant and machinery, should be undertaken.

Conclusions

The capital costs of home milling and mixing are now high, but careful calculation of the costs and benefits will allow a rational appraisal of investment priorities.

While it is tempting to cost installations in isolation from the remainder of the business, it is essential to check the effect on the financing of other areas of the business.

The potential savings on feed costs can be severely pruned by high cost, under-utilised plant.

The secondary aspects of home milling and mixing should be assessed with as much care as the potential cost savings. Sufficient time for management of the installation to ensure quality control and effective buying of raw materials where necessary, are a prime example.

Finally, feasibility studies are essential before installation of a unit is contemplated. The individual circumstances will obviously vary from one farmer to the next, but a feasibility study is particularly appropriate for those businesses with high levels of borrowing.

A Teaching Company Scheme in agriculture

C G Belyavin and R Jones

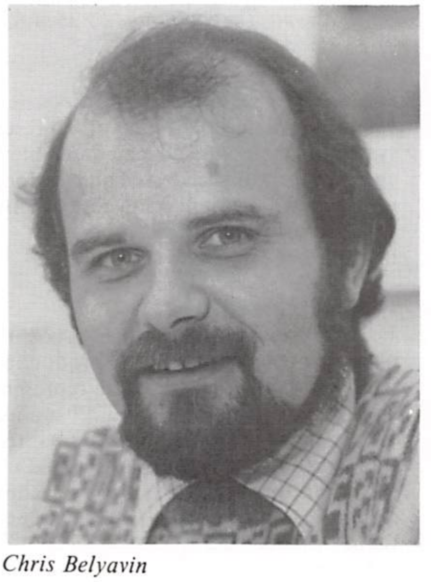
Introduction

TEACHING Company Schemes have been operating in the engineering industry for a number of years. The schemes are financed by the Science and Engineering Research Council in conjunction with the Department of Trade and Industry. Over one hundred such schemes are currently operating in the United Kingdom. They exist to enable manufacturing companies to join forces with academic institutions by introducing graduates into the Company who work under the supervision of staff at the institutions. However, until now, none of the schemes has been running in the field of agricultural engineering.

The first such scheme to be awarded to agriculture was announced earlier this year and will be undertaken jointly by CES Potters, Fillongley, Coventry; Harper Adams Agricultural College, Newport, Shropshire and The Polytechnic, Wolverhampton. Potters have become one of the leading United Kingdom manufacturers of pig and poultry houses, poultry cages, feeding and egg handling systems. They have recently moved into the export market and the directors recognise that if they are to continue to progress and remain competitive, then the company must be prepared to improve the design of its products, its manufacturing techniques and, where applicable, utilise new technology.

Harper Adams Agricultural College is a direct grant college which has both large engineering and poultry departments and diploma courses are taught in agricultural engineering and also poultry husbandry. There is an extensive poultry research and development programme undertaken at the Poultry Husbandry Experimental Unit associated with the College. Harper Adams and the Polytechnic at Wolverhampton work closely in the joint teaching of several agricultural technology and engineering courses and full use will be made of the well equipped Engineering Department at the Polytechnic where the facilities include the latest equipment to undertake computer aided design (CAD).

Chris Belyavin is the Senior Scientific Officer responsible for the Harper Adams Poultry Husbandry Experimental Unit and Roy Jones is joint Head of the School of Mechanical, Electrical and Production Engineering at the Polytechnic, Wolverhampton.



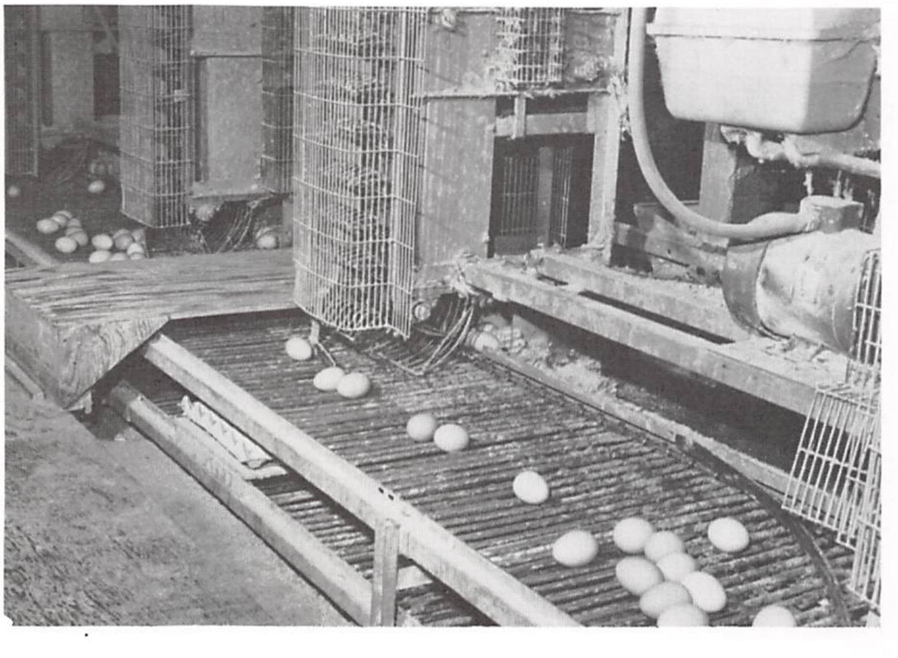
Chris Belyavin

Roy Jones

The Scheme

A grant of £103,000 has been awarded to this Teaching Company Scheme over a

Fig 1 An egg cross conveyor



period of three years and this includes a contribution of £21,000 from Potters. Three graduates will be employed, each for a period of two years meaning that two will be working on projects during the first year, three in the second year and only one in the final year.

Projects have been devised jointly by Potters, Harper Adams and Wolverhampton Polytechnic and are based on areas with a significant engineering bias. Initially, egg handling systems and feeding systems will be studied and later, a third area of study, building design, including manufacture and environmental control, will be introduced. Staff from Harper Adams will inject their poultry and engineering expertise while the Polytechnic staff will contribute through their specialist experience and research in the fields of building design, manufacturing technology, manufacturing systems and control and electronics. The engineering graduates employed in the Scheme as Associates will gain valuable experience for planning a future in British industry.

Fig 3 A typical modern poultry shed for laying hens

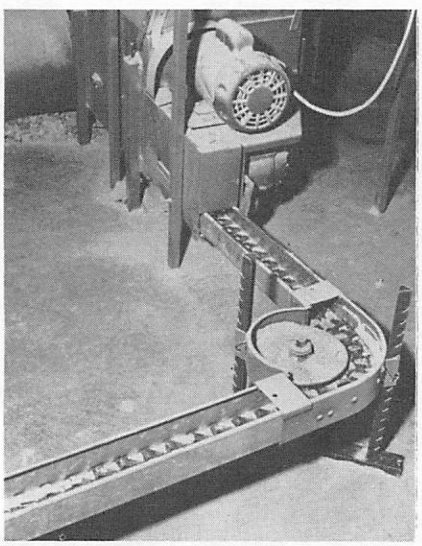
Project details

Egg handling systems

The trend towards larger poultry units has led to the installation of mechanised egg handling equipment on many farms which involves moving belts and conveyors (see fig 1). Unfortunately, eggs are not an ideal material to move mechanically and there are a number of problems associated with equipment presently available which results in dirty and cracked eggs. These have to be downgraded which results in an annual loss to the UK egg industry of £10–15 million.

The aim of this project will be to reduce the number of cracked and dirty eggs resulting from the collection systems and this will be achieved by improvements in the design and control of the handling and conveying equipment. The Associate will initially produce a cost and engineering evaluation of all proprietry egg handling equipment and determine where egg damage occurs with present systems. The factors which contribute to egg damage will be assessed and the long-term aim will be to develop cost effective designs of handling equipment to minimise egg damage.

Fig 2 A floor feeding system using a flat chain



Feeding systems

Feed represents at least 65% of the production costs in egg production, which in the United Kingdom represents an annual value in excess of £200 million. Inefficient utilisation of feed results from biological and physical wastage and it is estimated that these two factors account for approximately seven to ten percent of the feed costs.

In many cases, the food is conveyed to the birds using a flat chain in a trough. The design of the trough depends on whether the birds are housed in cages or in floor pens. Figure 2 shows a floor-feeding system. The transfer of the food from the holding bin onto the chain involves a crude slide arrangement above the chain which passes through the holding bin.

The overall aim of this project will be to design and produce feeding systems which would lead to more efficient utilisation of feed. The investigation will include the development of an efficient metering system which would control the amount of feed to the birds and the reduction of spillage by improvements in feeding trough design. The method of conveying the feed is critical to both aspects and will also need to be considered.

The Associate on this project will initially examine proprietary feed conveying equipment concentrating on the movement of feed from the hopper to the chicken with a minimum of loss. It will be important to establish where feed is lost and the reasons and to develop accurate means of measuring the quantity of feed delivered to chickens. The long term objective is to develop cost effective designs of feed conveying equipment to minimise feed wastage.

Building design

The third area of study, livestock building design, will not be introduced until the second year of the Scheme when the third Associate will be employed.

The design of livestock housing has not changed since the development of intensive systems some twenty years ago apart from a move towards larger buildings with high stocking densities. A typical modern poultry shed is shown in fig 3. The objective of this project will be to improve current building design by improving and incorporating environmental control methods, energy saving materials and manufacturing methods. Wherever possible modular design concepts will be used. Studies of the use of natural ventilation will be included.

Conclusions

The Associates will initially be based at Harper Adams where they will attend selected lectures on the poultry course, analyse the systems in operation there, and make visits to local farms. Thereafter, for the next three or four months, they will be based at Potters where they will examine all aspects of the design and manufacture of the Potter systems.

It may be that agricultural engineering has generally been considered the "poor relation" of the science of engineering. In fact, in the livestock sector alone, there are processes used which require fairly sophisticated equipment with high degrees of engineering input.

The award of this Scheme to agriculture may have several implications. Firstly, it provides a leading British company with the opportunity to improve the design and manufacture of its products. Secondly, it gives graduates a sound training for entering British industry and, thirdly, it leads to co-operation between two major teaching centres and a British company in the field of agricultural engineering.

Static pressure regain in bulk crop stores

D M Bruce

Introduction

STATIC pressure regain is a phenomenon which can occur in bulk crop stores, where air is distributed to the crop through perforated floors or ducts. It can cause regions of low air flow through the crop which may lead to spoilage. Unexpectedly perhaps, the low flow areas are in those parts of the crop nearest the fan. This item explains why static pressure regain occurs, and what can be done to minimise its effects.

Flow in an unperforated duct

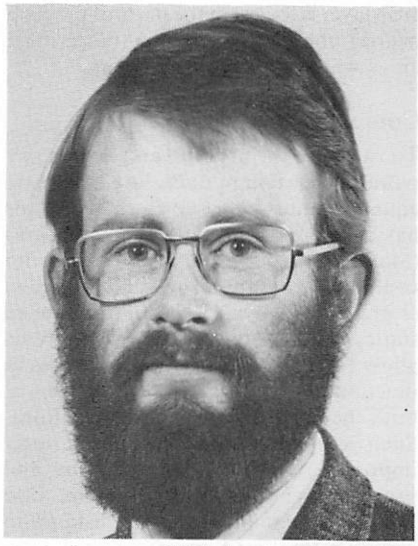
Consider air being blown down an unperforated duct. At a point in the duct, the air conditions are density ρ, kg/m^3, velocity v, m/s and static pressure p, Pa. The static pressure is that pressure acting equally in all directions; the pressure that would be measured by a manometer with the open face of its tube parallel to the flow. The air also has velocity pressure, $1/2\ \rho v^2$, which only appears as a measurable pressure when the flow is brought to rest. Thus, a manometer with its open end facing into the flow will measure the static plus velocity pressures, called the total pressure. Along the duct, the density and velocity (and therefore velocity pressure) are constant, but frictional drag and viscous forces cause a static pressure loss, and a corresponding total pressure loss.

David Bruce is in the Crop Engineering Division of the National Institute of Agricultural Engineering where he specialises in grain drier modelling.

This item is a summary of a talk given to the Institution of Agricultural Engineers Crop Drying and Storage Group on 6 December 1983.

Flow in a perforated duct

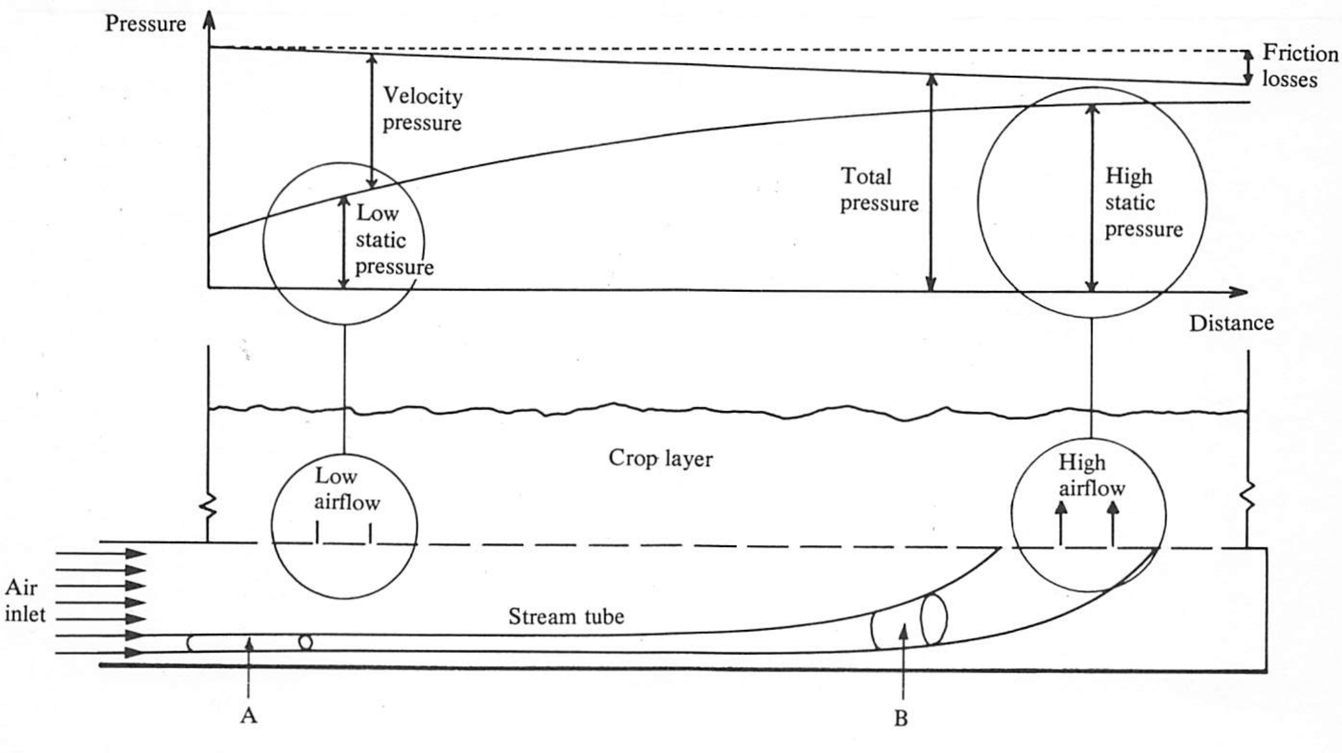
In a perforated lateral duct, air enters at one end and flows along the lateral, emerging through the perforations. Within the duct, it is the *static pressure* which forces air through the perforations and up through the crop layer (fig 1). How does the static pressure change along the duct in this case? Consider a slug of air entering the duct, (A, fig 1 bottom) which will emerge into the crop some distance along (B, fig 1 bottom). It flows down a stream tube, along which the mass flow rate of air is constant. As the slug moves along the duct, more air around it flows out through the crop, so the cross-sectional area for the slug increases, shown by the widening of the tube. Because the mass flow rate and density of the air are constant along the stream tube, the velocity of the air slug



must decrease. This leads to a fall in velocity pressure along the lateral (fig 1 top).

But along the duct, total pressure falls only slightly because frictional losses are small. Therefore, the static pressure increases along the duct because at every point, total pressure is equal to the static pressure plus the velocity pressure. Thus static pressure is *regained* from the velocity pressure. The static pressure increase towards the closed end of the duct causes higher flows through the crop there, and lower flows at the inlet end (fig 1).

Fig 1 Single perforated duct:
top – variation of pressures along duct;
bottom – vertical cross-section of duct and crop showing path of a slug of air and flow up through the crop;
A – high speed air, velocity pressure high, static pressure low;
B – air speed reduced, velocity pressure regained as static pressure



In a main duct which feeds lateral ducts spaced along it, the same effect occurs, so there is a lower static pressure at the fan end. For these reasons then, the static pressure, and air flow through the (even) crop layer is lowest in the parts of the crop nearest the fan. These are the critical areas where spoilage may occur.

Computer models

To calculate the pressure and flow at any point in a system of ducts, the governing equations must be set up and solved. This has been done for relatively simple cases (Marchant and Nellist 1977a,b) and computer programs are available (Nellist *et al* 1977, Dallyn 1977). In addition to static pressure regain, these programs allow for wall friction, pressure losses at junctions and the resistance to air flow of both the crop and the duct perforations. Such computer models have greatly improved the understanding of flow and pressure phenomena in duct systems. One could use these programs for instance to choose a total air flow into a given crop store, and then calculate the flow through the crop at chosen points in the store. By altering the input data to the program, one could then examine the effect of say, duct spacing, duct length, depth of crop, etc. on air distribution. Obviously this type of model is potentially useful as a design tool.

Onions — at risk in store

The model can be used to see how crop resistance and air flow requirements influence the static pressure regain, and thereby highlight why onions in bulk are potentially at risk due to low air flow. Two factors are at work; high air flow requirement and low average duct pressure. In fig 1 top, the static pressure level at any point along the duct can be thought of as consisting of a base level, (the static pressure at the air inlet) plus an amount regained from the velocity pressure. The amount of regain depends on the inlet velocity to the duct, which in turn depends on air flow required by the crop and the duct area. For a high air flow crop such as onions (0.12 m^3s^{-1} t^{-1}) the regain is therefore higher than for a low air flow crop such as grain (0.05 m^3s^{-1} t^{-1}), if duct area is the same in both cases.

A given rise in static pressure along the duct will have a proportionately greater effect on the outflow when the base static pressure in the duct is low. Onions have a lower resistance to air flow than grain, and therefore the pressure needed to force the required air flow through the crop is lower for onions (250 Pa) than for grain (900 Pa). These two factors combine to decrease the static pressure, and hence the air flow through the crop at the entry end of the duct in relation to the closed end. Thus, when dried over identical laterals, onions are a worse case for potential trouble.

Preventing uneven air flow

What steps can be taken to even out the air flow through the crop?

(i) The store should be designed to keep air speeds below 10 m/s. At this speed, the velocity pressure is 60 Pa, compared with a mean duct static pressure of 250 Pa for onions and 900 Pa for wheat, each 3 m deep.

(ii) Lateral ducts can be tapered or stepped to reduce the cross-sectional area to towards the closed end. This keeps air speeds more nearly constant, and thereby reduces regain.

(iii) Use a blowing rather than a suction arrangement. Though this is normally done anyway to direct the air through heaters, it is also the better system for even air distribution. Wall friction and viscous forces, cause a static pressure drop in the direction of air flow. In a blowing system, this effect is more than counteracted by the regain effect. If suction is used, however, the regain and friction effects combine to make the differences worse.

(iv) Other actions include using higher resistance ducts, reducing the perforated area towards the closed end of the ducts, inducing turbulence by obstructions in the ducts and piling the crop higher at the closed end. These actions can all increase the resistance of the duct system and care should be taken that the fan can deliver enough air at the higher pressure at which it will operate.

References

Dallyn S (1977). Calculation of air pressures and flows in systems of lateral ducts for crop ventilation. Div Note DN/DS/813/07005. Natn Inst agric Engng, Silsoe. (unpubl).

Marchant J A, Nellist M E (1977a). Air pressure and flow in ducted crop drying systems. 1 Single ducts. *J agric Engng Res*, **22**, 303–310.

Marchant J A, Nellist M E (1977b). Air pressure and flow in ducted crop drying systems. 2 Systems of ducts. *J agric Engng Res*, **22**, 311–319.

Nellist M E, Dumont S, Marchant J A (1977). Calculation of air pressure and flow in single perforated ducts for crop ventilation. Div Note DN/DS/799/07005. Natn Inst agric Engng, Silsoe, (unpubl).

Air flow and temperature distribution problems in root crop stores

D I Bartlett

Air Distribution

DAVID BRUCE'S paper has described very clearly the mechanism and effects of static regain in discharging duct systems. The following practical problems and solutions arise as a consequence of regain.

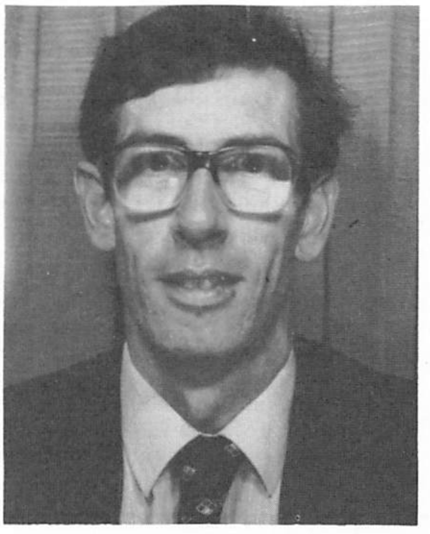
1. Air starvation can occur in laterals immediately adjacent to fan discharges. The discharge velocity from the types of fans used in agricultural crop drying installations are in the range 15 to 25 m/s. For economic reasons (building costs), it is normally considered impractical to have a significant length of non discharging duct in which the high discharge velocity can be diffused to an acceptable level before lateral discharge begins.

   The recommended design velocity for main ducts is 10 m/s. In practice, this velocity is exceeded for several metres downstream of the fan discharge in a typical installation. The problem is to diffuse the fan discharge as quickly as possible in order to economise on non-discharging main duct and to make full use of the main duct section that is provided. A transformation type diffuser is only effective up to an angle of about 11°; beyond this, the boundary layer will detach from the surface which will then have little or no influence on the diffusion of the jet. A 30° diffusion angle is possible if a Vortex Diffuser is employed. The Vortex Diffuser comprises a stabilised vortex as shown in figure 1. Air in the main jet is pulled out without breaking away. The vortex is stabilised by continually removing the boundary layer that develops between the vortex and the surfaces within which it is trapped. In addition to this, a fence prevents the vortex being carried down the main duct with the expanding jet.

   In practical terms, the removal of the boundary layer to stabilise the vortex is achieved by connecting a short section of duct back to the fan

David Bartlett is the National ADAS Crop Storage Specialist based at the Agricultural Development and Advisory Service Liaison Unit, National Institute of Agricultural Engineering, Silsoe.

This item is a summary of a talk given to the Institution of Agricultural Engineers Crop Drying and Storage Group on 6 December 1983

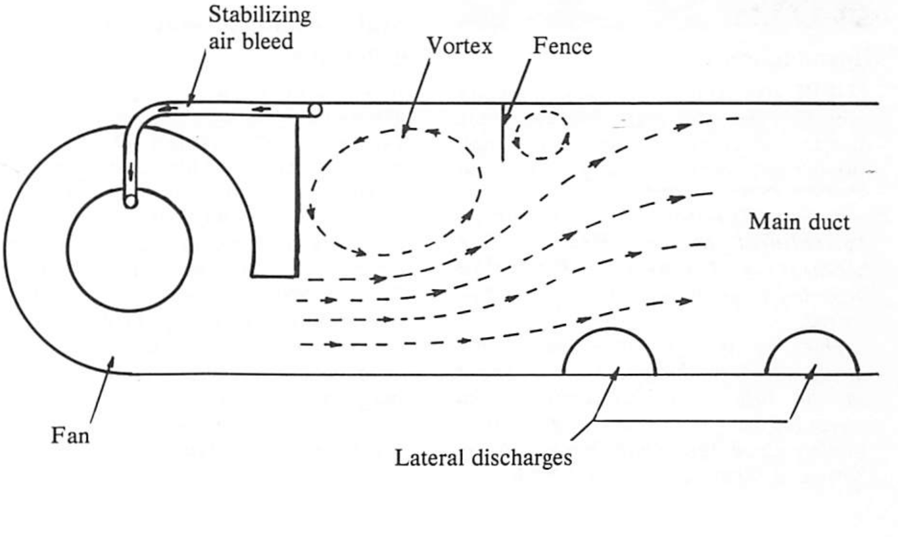


   inlet. The positioning of the fence and the quantity of air that must be drawn off to stabilise the vortex, are most simply arrived at on a trial basis. Static pressure measurements in the main duct or discharge velocities from lateral outlets will give a clear indication of the effect of modifications. Where a design must be established prior to construction, water table analysis may be helpful.

2. The design of ventilating systems for crops with low resistance to airflow can prove difficult. Reasonably uniform air distribution can be expected if the ratio of static to velocity pressure at all points in the ducting system approximates to 6:1. Where there are good reasons to deviate from this standard it may be necessary to resort to tapering ducts and/or grading outlet sizes in order to achieve an acceptable distribution.

   In some installations where excessively large ducts have been used, the system resistance has been so low that the effect has been that of a fan discharging into a large open space: The duct fails to convey the air to its extremities because the resistance to discharge is so low that it can escape before travelling to the end of the duct.

Fig 1 Vortex Diffuser



Temperature distribution

In order to follow the bulk drying recommendations for onions, a heater capacity capable of raising the drying air flow through 15–20°C is necessary. In some installations, particularly where the heater is mounted downstream of the fan, there has been very poor mixing of the heated and unheated air in the main duct and as a consequence some laterals have been supplied with air at up to 20°C above the desired level. The effect on the crop has been disastrous.

Poor mixing of heated air brings with it attendant problems of control. If the air is improperly mixed, it is very difficult to chose a representative location for the temperature control detecting element. A further complication in some sites has been the difference in response rate of the detector and the heater control. Slow response of the detector has resulted in control instability and in some cases excessive overshoot, again resulting in dangerously high drying air temperatures.

Solutions to the air mixing problem are not easy and are specific to individual installations. In general, air mixing can only be achieved at the expense of some additional pressure drop or by providing a long mixing path between the introduction of the heat and the first point of discharge.

Air conditions in crop stores

The introduction of spray foam for insulating and sealing agricultural storage buildings has accentuated the problem of condensation control within these structures. Most difficulties have been associated with potato stores, but the same problem will in principle arise in any close crop store. Economic considerations dictate that the space enclosed by the shell of the building is as fully used as possible. The trend is towards greater storage depths and shallower head spaces. Individual storage units are becoming larger. The combination of these factors results in decreasing values of the ratio of surface area of the shell to mass of potatoes enclosed.

Root vegetables are living organisms that continue to respire during storage. Respiration produces both heat and moisture. The proportions of heat evolved as latent and sensible, depend on the air conditions within the building. With the present levels of loading, sealing and insulation it is impractical to control storage conditions without providing some air movement. Practical experience suggests that it will be necessary to provide ventilation to remove moisture from the store when ventilation is not required for temperature control purposes (particularly when outside conditions are cold.) Only limited quantities of water can be stored on the building structure as condensation before run-off starts. If these conditions persist for any length of time, the sure result is localised rotting of the crop.

Roof space ventilation provides a means of rejecting moisture from the building without ventilating the crop itself. The design problem is one of deciding on an appropriate ventilation rate to maintain a moisture balance. Under natural convective ventilation root crops will be capable of saturating the air passing over them. The rate of water loss is therefore governed by the moisture carrying capacity of the air and not by the crop's ability to give up moisture. The rate of moisture rejection by potatoes, taking into account their respiration rate in a 3 m deep stack and the air flow generated by natural convection, is calculated to be 0.16 kg/t day. If it is assumed that ambient conditions are only suitable for rejecting moisture for 25% of the time, then a ventilation rate of 0.0036 $m^3 s^{-1} t^{-1}$ will be adequate.

The introduction of cold air into the headspace in a store must be carried out with care, since if it impinges directly on any surface, local cooling to below roof space dew point can occur, resulting in localised condensation. Careful design of the air distribution system will avoid their problem. Alternatively, an effective air mixing system which recirculates the air in the roof space can be considered.

In existing stores a simple improvement to the present situation may be obtained by allowing air to escape from the top of the main air duct, thus by-passing the crop.

Parallel operation of private generators with Electricity Boards' low voltage network

P Wakeford

Introduction

THERE has been considerable publicity over the last ten years for anaerobic digester schemes on farms. A small number have been built, largely financed by capital from outside agriculture, and, on occasion, methane has been used to power generators to produce electricity. At this stage, two common errors seem to occur. Firstly, the enthusiast mentions that surplus electricity will be fed back into the grid (with no mention of capital costs) and, secondly, units sold back will produce a high cost, per kWh, even, on occasion, equal to the current area board cost for selling electricity. In order to clarify the situation, in relation to (a) parallel operation of private generators with Electricity Boards' low voltage output, and (b) the cost basis of selling units back, this paper outlines the complexities involved.

Peter Wakeford was formerly Agricultural Section Head of the Electricity Council's Marketing Department, from which post he has now retired.

This Item is an extract from a paper entitled: "Self production of electric power on the farm – an evaluation", and presented at the 15th International Conference on Agricultural Mechanisation, Zaragoza, Spain on 13 April 1983.

Mains excited, asynchronous generator

It would be unwise to rely on methane-generated electricity on farms for the supply of electricity as a whole, or even part of it, due to the high cost of methane generation, so it is essential to make arrangements with the electricity authority for a mains supply. There are several types of generator available. In the context of satisfactory parallel operation on low voltage farm networks, the most acceptable is the mains excited asynchronous generator, ie the rotating magnetic field is excited by the mains, and the rotor is then driven above synchronous speed in the same direction as the field. A rotor torque is induced, acting against the direction of rotation. The prime mover (ie the gas engine) has to overcome this torque to maintain the speed above the synchronous value. The generator thus receives power from the prime mover and transfers this power to the supply system. The advantage of the mains-excited asynchronous generator is that no exciter, no complicated governor and no synchronising equipment are needed. The disadvantage is that the supply network has to supply the lagging reactive power to magnetise the machine. This involves the Boards in extra losses, but does not involve any technical problems other than that of compensating for the low power factor.

Mains excited generators will normally cease generation if the mains supply fails as the required magnetising current will not be available. However, generation could continue by self-excitation if the capacitance of the connected network is sufficient. The output voltage and frequency would differ from normal and protective devices must be installed to prevent generation under these circumstances. Power factor correction banks should not be connected electrically close to asynchronous generators as they could cause self-excitation. It is recommended that self-excited generators should be three-phase, since the extent to which single phase generators can be accepted on the network is extremely restricted.

In operation, the usual practice with an

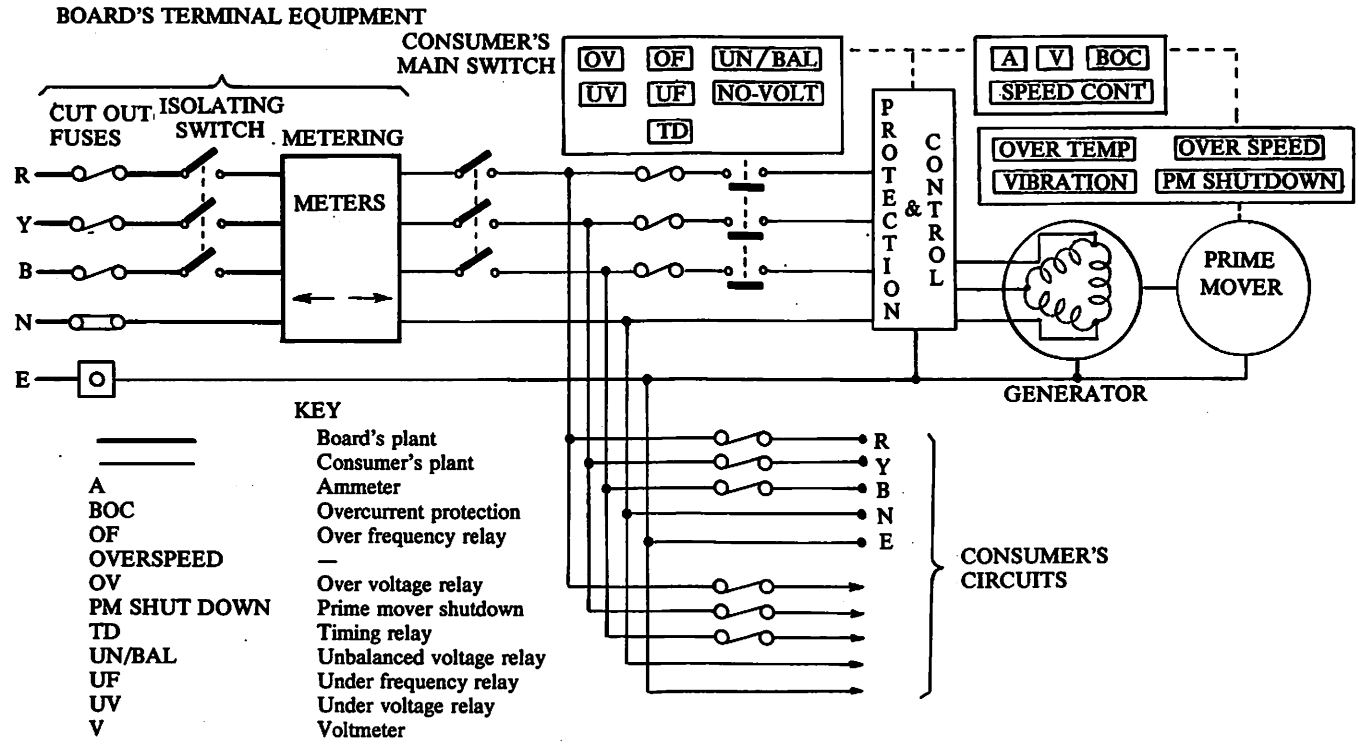


Fig 1 Typical control, protection and earthing arrangements for a directly connected mains-excited asynchronous generator

asynchronous generator is that below synchronous speed it runs as an induction motor. The output circuit breaker is closed while the prime mover is at rest. The motor action then turns the prime mover until sufficient rotational speed is achieved for the normal motive power to take over. This motive power then raises the speed of the prime mover above synchronous speed and the machine begins to generate. If the speed of the prime mover subsequently falls below synchronous speed, the output circuit-breaker is opened in the normal manner. If the speed of the prime mover increases substantially above synchronous speed, the output circuit breaker is again opened and the prime mover brought to rest.

Figure 1 shows typical control, protection and earthing connections for a directly connected mains-excited asynchronous generator. If the generator power exceeds the demand of the consumer circuit, then, unless there is an agreement between the Board and the farm consumer for the Board to purchase electricity, any spare electricity would feed back into the Board's system, and normally a stop would be incorporated in the kWh meter mechanism to prevent reversal of the readings.

Any agreement made between the Electricity Board and a farm consumer for parallel operation of a generator requires the installation and payment by the consumer of adequate protective equipment to ensure that the operation by the private generator does not introduce a hazard to the general public, the farmer consumer or his staff, other Electricity Board's consumers, or the Board's employees. The Electricity Council guidelines (1981) set out Network requirements (relating to voltage changes, limits and permitted fluctuations, maximum switch-on and fault level) and Protection requirements (relating to integrity of mains supply, voltage protection, and voltage imbalance protection, frequency and overspeed protection), the safety of the private installation, and commissioning and testing by the consumer's engineer, which must be witnessed by the Electricity Board, together with requirements for written records of protection settings and results of commissioning tests. The guidelines also detail operational requirements regarding isolating switches, and identification of Board's and consumer's equipment, and the provisions to be made for earthing.

Tariffs for parallel operation and provision of mains supply as standby

In the few farming situations in which the farmer produces methane and uses it to generate electricity, he might be interested in using this self-generated electricity to substitute for that which he had previously, or would otherwise have, obtained from the public supply. As has been indicated it would be almost certain that he would require the mains electricity in this situation as a standby.

He may also consider that if he has spare electricity it would be to his advantage to sell this back to the Electricity Authority, and so recover part of the costs of his investment in private generation by this means.

Both these situations are catered for by Electricity Boards in Great Britain, and the general principles have been set down (Fowler 1982).

In this paper, the main arrangements are described, but for precise and detailed data applicable to specific situations, reference should be made to the Electricity Council, individual Electricity Boards and the CEGB Bulk Supply Tariff 1982/83.

Where a private generator is operated in parallel with the public system, the public supply will normally be given under a maximum demand tariff with separate metering of the energy supplied during the day (17 hours) and at night (7 hours). If the tariff includes a separate service capacity charge (associated with the self-generation) this will be set at a level commensurate with the maximum power anticipated, irrespective of whether this is an import or export of energy. Thus, any additional costs of system reinforcement and protection, or abnormal metering, incurred by the Electricity Board, as a result of the parallel operation, must be borne by the farm consumer.

If the private generator wishes the Board to standby to a part or all of his generating capacity, or if he wishes the Board to purchase electricity that is excess to his requirements, then standby and purchase terms described below will apply. These, together with the basic charges in the maximum demand tariff may be combined to form the total agreement between the two parties.

Standby terms

The costs attributable to standby, which are additional to the usual costs of giving the supply are:-

(a) the capital costs of the connection

(and/or where existing facilities are being utilised, an annual charge based on appropriate proportion of them having regard to replacement cost); and

(b) annual capital charges and operating and maintenance costs in respect of Generating Board or Electricity Board assets (generators, lines, transformers etc, and the connection) specifically incurred for the standby supply to the extent that they are not otherwise recovered.

There is some variation across the country in the way in which Electricity Boards present these changes. A common way of recovering them is as follows:-

	£/kVA per annum
Service capacity charge (as in normal MD tariff; covers Board's assets local to the supply)	6.50
plus standby capacity charge (covers Board's assets at higher voltages)	3.50

If the supply is taken up then maximum demand charges, kWh rates and fuel cost adjustment apply, similar to or the same as those in the maximum demand tariff. In this instance there is a rebate of the standby capacity charge, either fully or in part, by one-twelfth for each kW or kVA of standby actually used in a month to avoid recovering certain costs twice.

Terms for purchase of suprlus units

Electricity Boards are prepared to negotiate with private producers for purchase of electricity at prices determined from the Boards avoidable costs. Payment for energy (kWh) is based on the kWh rates in the CEGB's Bulk Supply Tariff (BST). In the case of small, remotely located, generators operated intermittently the price offerd would be probably about 40% below the Bulk Supply Tariff to reflect the sub-optimal location, unpredictability of supply and additional operational and protection costs incurred.

The costs of metering needed to record the exported electricity must be borne by the private producer, and the responsibility for billing rest with the producer. As these costs are high in relation to the return from selling electricity back to the Board, it is understood that there are, as yet, no examples of this occurring on farms producing methane for electricity generation.

Summary

In Agriculture, if an anaerobic digestion plant is being considered, it is important to incorporate realistic costs for the equipment required should electricity generation be contemplated. It is unlikely that it would be economic to consider parallel operation, due to the high capital cost of equipment and the small quantities of electricity involved.

References

Electricity Council (1981). Notes of guidance for the parallel operation of private generators with Electricity Boards Low Voltage Networks. Engineering Recommendation G47.

Fowler G J (1982). Electricity Tariffs and Private Generation. IEE Colloquium on Tariffs and Renewable Energy Sources. March.

The Agricultural Engineer

Instructions to authors

1 Preparation of the text

The manuscript should be typewritten with double spacing and wide margins on one side of A4 paper. The original and one copy are required for editing and printing.

2 Length of paper

Papers for presentation at Conferences *must not* exceed 5,000 words in length.
Papers for direct publication must not exceed 10,000 words in length.

3 Headings

All main and sub headings should be in lower case typescript except for the first letter of the first word, proper nouns and generic names. The main headings should be typed as a separate line of text with an extra line space above and below and without any underlining. Sub headings should precede the first line of the paragraph to which they relate.

4 Format

Underlining should be used only to denote italics for parts of the text and for scientific names of pests, plants, etc.

There should be no stop at the end of any heading or caption unless the last word is an abbreviation of which the stop is a part.
For example:
Yield stability in Vicia faba in the United Kingdom.

5 Title page

The title page should include: the title, and the name(s) of the author(s), their affiliation(s) and passport photograph(s).

6 Summary

The manuscript should include a summary of not more than 400 words.

7 Abbreviation of units

The SI system should be used throughout the text as well as in the tables and figures, British Standard PD5686 (1972). The plural of all abbreviations is the same as the singular, eg kg (not kgs). The solidus is used to denote "per" except in the case of more than two units when negative indices are used, eg m/s and W $s^{-1}t^{-1}$.

8 Symbols

Symbols should be defined in the text where they first appear. Where many symbols are used in the paper, they should be listed in a "key to symbols".

9 Illustrations

All illustrations should be numbered by arabic numerals.

Drawings should be on tracing paper, artboard or faintly lined graph paper in black ink. Use stencils, flexicurves or Letraset in preference to freehand lines. Lines finer than 0.4 mm do not give adequate quality of reproduction.

The original diagrams should be submitted without labelling or captions which should be given on an attached photocopy.

10 Photographs

Photographs should be supplied as glossy prints, unmounted and unattached. Full plate prints are preferred.

For part reproduction of a photograph, an overlay should be attached and the relevant area marked with a soft pencil.

The figure number and the top of the photograph (if not explicit) should be indicated on the back. The caption should be provided on a separate page.

11 Tables

Tables are numbered in arabic numerals with the caption at the top. Do not use vertical lines to delineate columns. Only use two horizontal lines one below the column titles and one at the foot of the table.

12 References

References in the text should be cited as the name(s) of the author(s), followed by the year of publication (Smith and Jones 1970). Multi-author works should be quoted in the form: "Smith *et al* (1982) developed . . ."

The reference list should be in alphabetical order according to the Harvard system with abbreviations for the title of the journal or source in accordance with the World List of Scientific Publications, 4th ed. The preferred style is:

(a) for periodicals
Smith A B, Jones C D, Frank E F (1982). A mathematical simulation of grain drying. J agric Engng Res, 12, 105–123.

(b) for books
Cochran W G, Cox G M (1964). Experimental designs. 2nd ed New York, Wiley.

As in the text of the paper, underlining indicates the use of italics.

13 Appraisal

(a) *Scientific papers* Papers submitted to the Journal may be afforded the opportunity of being refereed before publication if the author so requests and if the paper contains a record of original work or presents an original commentary not previously published elsewhere. Refereed papers will be annotated accordingly.

(b) *Conference papers* Conference papers are not generally refereed but may be if the author so requests and if the refereeing process can be completed before the Conference Proceedings are due to be published. Refereed papers will be annotated accordingly.

(c) *Technical articles and reviews.* Technical articles and reviews are not normally appropriate for refereeing but this does not reflect either on the standard of the paper or the relevance of the material.

14 Copyright

Submission of a paper for publication implies the transfer of the copyright from the author(s) to the Institution of Agricultural Engineers. Permission to reproduce all or part of any paper should be requested from The Secretary.

The Honorary Editor, The Institution of Agricultural Engineers, West End Road, Silsoe, Bedford MK45 4DU.
Telephone: 0525 61096.