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CONTENTS

Front cover: Top - Drive line measurements on a drum mower-conditioner.
Lower left - Rig measurement of overload clutch performance.
Lower right - Drive line torque pattern of mower shown above.

Who needs agricultural engineers ?

Asks Brian Stenning

THE answer to this is evidently "more people than actually realise it", and this lack of realisation almost certainly stems from the difficulty which the agricultural engineer has in being specific about his own role in society.

At a conference of the Silsoe Society, held recently at the National College of Agricultural Engineering, speakers from a wide range of agricultural and associated organisations provided their own answers to the above question. Each speaker had his own definition of agricultural engineering and there were very obvious differences surrounding the main theme. Perhaps the greatest interest lay in these differences rather than the similarities. The very existence and breadth of the variations emphasised the need for a man who has a broad background, ranging from appreciation of land resources to an ability to design and build farm machinery, from a knowledge of crop storage problems and techniques to an awareness of economic and sociological problems which arise from changes in agricultural policy.

This is certainly not to say that the agricultural engineer is never an expert, or a specialist. As in other walks of life, the most successful and needed man is often he who has special skills backed up by a wealth of broad experience. But it is clear, in a field where such a breadth of disciplines is involved, that the expert need not necessarily be a specialist.

The agricultural engineer plays a leading part in a wide range of activities. Research and development posts demand a man who is innovative, good at design and has a well formed sympathy at the interface of engineering and agriculture. Consultancy, often in overseas situations, requires a man who can assimilate ideas from specialists of other disciplines to form an overall appreciation of development plans and their likely influence on human and environmental relationships. The manufacturer seeks overall engineering ability and an awareness of marketing implications. The farmer relies on the agricultural engineer to bring together the interests of the producer and those of the industries which supply him with his hardware.

There is no doubt that in the developing countries the agricultural engineer is much in demand, as an adviser, designer, supervisor of installations and in the ever present problem of maintenance. And on the American continent the very size and activity of the membership of the American Society of Agricultural Engineers emphasises the acceptance of the profession. The wealth of knowledge at the elbow of the agricultural engineer is clearly seen from a glance at the annual index of any reputable journal in the field.

So the conclusion must be that the agricultural engineer has a vital part to play in the maintenance and improvement of world food supplies. He must be a man of broad interests and a sympathetic understanding of human problems. His training must be, at the outset, comprehensive in its coverage but must provide a firm foundation for later specialisation should he wish to pursue it.

There is a place in the world of agricultural engineering for both the generalist and the specialist, the problem is that of providing an acceptable professional engineering umbrella for this group with its many and varied interests.

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Whole crop cereals: harvesting, drying and separation

B Wilton

1 Introduction

WITHIN a generation nearly all the heavy jobs on UK farms that were done by hand, or with the aid of unsophisticated equipment, have been mechanised. In some cases equipment has simply grown in size and complexity, in others new concepts have been introduced. When good conditions prevail the work rates that can now be achieved are extremely high, but in difficult conditions — which in the case of field work usually means when it rains — the performance of even the most sophisticated equipment is affected. Harvesting operations are particularly susceptible to delay — old elevator diggers and hand pickers are brought out to rescue the potato crop when the weather deteriorates, and redundant single-row sugar beet harvesters reappear in emergencies. Unfortunately a wet grain harvest causes problems of a different order of magnitude which cannot be solved by falling back on older equipment.

Farmers who grow grain in maritime climates have become resigned to harvesting only when the weather is dry, because their harvester, which was originally developed in the continental climate of the prairies, cannot handle wet crops. The fact that the process of harvesting our major arable crop is still so completely weather-dependent ought perhaps to give some cause for concern.

The inability of the combine to work in wet crops has several important consequences which are worth listing:

(i) Harvesting cannot commence until at least a week after the crop has reached its maximum grain dry matter yield; this occurs at a grain moisture content of 40 – 35%. After this moisture content has been reached all losses through shedding and pests are cumulative.

(ii) Harvesting progresses spasmodically with some exceptionally long days and some days when none is possible. Seldom is it possible to commence harvesting at the normal time of starting work in the morning.

(iii) National combine capacity has now risen to a level such that in an 'easy' season excess capacity and capitalisation is regarded as some form of insurance, whilst in a 'difficult' year some crops remain unharvested.

(iv) In some areas where excellent cereal crops can be grown, mainly because summer rainfall is adequate, cereals have disappeared because they ripen late and harvesting with a combine has been found to be excessively risky. The usual alternative crop in these areas is grass, which means that in order to supply livestock with dense energy foods, cereals have to be bought in..

Two further criticisms of the combine are that because of its limited size some losses of grain are inevitable, and that in picking up the material discharged from the rear of the combine some of the most valuable feeding material, namely the leaves and chaff, is left behind.

If some method of harvesting cereals which is less affected by crop moisture content is to be developed it would be advanageous to use equipment which has other uses on farms. Forage harvesters, which have emerged since the present form of the combine was established, are the obvious choice; they have, after all, been developed to harvest graminaceous crops. In passing, it is interesting to speculate whether combines would have developed in the way they have if high capacity forage harvesters had emerged 30 years earlier.

2 Chop threshing

The forage harvesting of cereal crops formed the basis of the chop-threshing system used fairly extensively in eastern European countries between 10 and 25 years ago. The crop was usually windrowed and finally fed through a stationary separator (usually a modified thresher). The system was eventually abandoned for the following reasons:

(i) combines became more readily available;

(ii) losses of grain caused by the weathering and handling of the swath could be high, particularly in unfavourable seasons;

(iii) the difficulty of separating damp grain from damp straw.

Chop threshing was studied at the University of Durham in the early 1950's by agricultural engineers who used an early forage harvester — this was essentially two rotary disc cutters and a crude chopper/blower. Since that time two developments which could be relevant to cereal harvesting have taken place — forage harvesters have changed dramatically, and a number of rotary drum crop driers have been installed on UK farms. It is suggested that this equipment might form the basis of a chop threshing/drying system of harvesting cereals which in some circumstances might compete with the combine. One particularly fortunate aspect of this approach is that this equipment is frequently under-employed at the time cereals mature, because of a shortage of green forage to process.

3 Experimental work at Nottingham

Although the idea of harvesting, drying and processing whole crop cereals was studied by Baker in 1967[1], it was 1970 before a crop was handled in this way; the material was milled and pelleted, and attention was concentrated on establishing its worth as a feed for beef cattle and sheep[2].

Then followed the work of Shamsham[3], who introduced both oscillating equipment to separate the crop into various fractions, and a small prototype furnace designed to burn straw. Since 1974 the the oscillating separator has been replaced and a straw-burning furnace which is large enough to provide all the heat required for drying has been added to the plant.

3.1 Harvesting and transport Crops of wheat, barley and oats have been cut with a John Deere 34 precision chop forage harvester fitted with a cutterbar attachment and a six-bladed cutting cylinder. The only problem encountered was the loss of whole heads of grain when cutting laid crops, particularly of barley; this could presumably have been overcome by fitting combine-type grain-lifting fingers and an adjustable reel. Losses of single grains from the cutterbar and the hessian lined trailer were negligible, but approximately 4% of the grain was visibly damaged.

A relatively small trailer was used (nominally 3 t capacity) and in this the density of the chopped crops was approximately 135 kg/m^3.

3.2 Drying The plant was a standard Van den Broek single pass drum drier with an evaporative capacity of 1500 l/h on a wet crop. In order to minimise the risk of fire the maximum inlet temperature was kept down to 400°C (some 500°C below the normal operating temperature) and the maximum rate of evaporation recorded was 608 l/h.

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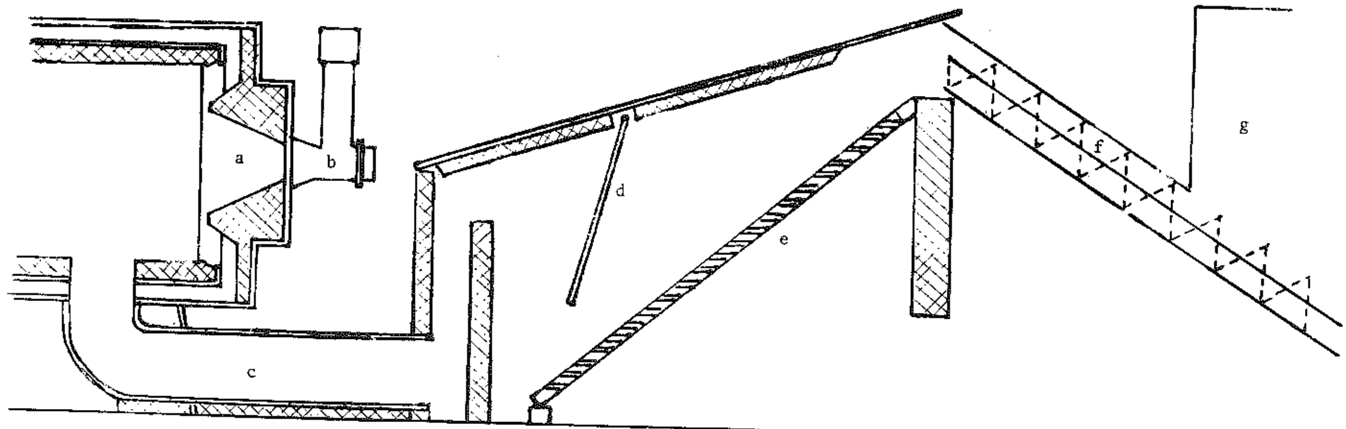

Fig 1 Straw-burning furnace linked to a conventional oil-fired air heater supplying a rotary drum crop drier.
a: Quarl, b: Oil burner, c: Duct, d: Adjustable baffle, e: Sloping grate, f: Auger feeder, g: Hopper for chopped straw.

It was found that straw, chaff and leaf material were all conveyed through the plant pneumatically and emerged within a few seconds of entry, in contrast grain tended to be mechanically conveyed and took several minutes to pass through the system: the overall effect was that all components had similar moisture contents on discharge.

3.3Separation By the time the crops emerged from the drier all the grain was threshed out of the head, and all the awns (or glumes) and many of the leaves were broken into relatively small pieces; the straw, however, had apparently suffered little further damage. Shamsham[3] used a straw walker/sieves/fan assembly taken from a combine to effect separation, but this approach was later abandoned primarily because of the dust it created.

If separation is required an inclined rotary sieve (0.8 m dia, 3.5 m long with 12.5 mm dia perforations) is now used as a first stage separator, and this takes out the longest pieces of straw. Material which passes through the screen includes whole and broken grain, leaf material, some short pieces of straw, chaff or awns, and weed material: if further separation is required this is fed through an enclosed aspirated oscillating screen cleaner to give grain and a mixture which has a considerably higher feeding value than straw.

3.4Straw-burning furnaces Furnaces to burn both solid and pulverised fuel are common; however no appropriate designs for light fibrous fuels could be found in the early 1970's. Domestic straw-burning boilers of Scandinavian design seemed an inappropriate starting point and advice pointed towards a simple underfeed stoker approach. A prototype underfeed furnace was built but soon abandoned in favour of a sloping louvred grate furnace, fitted with an internal baffle to deflect smoke through the hottest zone (see fig 1). Flue gas temperatures of 1000°C were recorded; however the highest thermal efficiency (73%) and lowest smoke levels were obtained at 550°C.

The present furnace has a grate area of 3.0 m^2 and has provided sufficient heat to dry whole crop barley from 39.3% mc to 14.2% mc while using only part of the straw from the separated crop (dry straw has an energy value of some 19 MJ/kg).

4 Discussion

The agronomic and management advantages of whole crop cereal harvesting are probably the easiest to visualise. It can be timed to precede the time when the seed of a troublesome weed, wild oat, is shed, and early harvesting will stimulate the growth of under-sown grass crops and give more time for either the establishment of forage catch crops or for stubble cleaning and cultivation operations. It is much more difficult to evaluate the benefits of being able to gather that portion of the crop which the combine/baler combination leaves behind in the field, and to do it at a steady rate which is independent of weather conditions.

Capital aspects of the process are probably even more difficult to evaluate. The work at Nottingham has centred on a conventional high-temperature rotary drum drier: such plants are relatively expensive but they are usually operated for at least six months each year. From May to July operation is usually continuous but at other times it is difficult to work at maximum capacity – whole crop cereals could take up some of this slack in August and September. Alternatively some less expensive plant could well be developed – it would even be possible to design a storage drying facility for whole crop cereals or to consider treating moist crops with caustic soda or a chemical preservative.

The straw-burning furnace part of the system tends to divert attention from the other, potentially more important aspects. Dramatic changes in energy costs since this research programme was initiated have resulted in the installation of straw-fired boilers in farm houses throughout Europe, and a research and development programme intended to produce equipment to burn large straw bales has been established in Western Germany. Attention has also been drawn to the fact that the energy requirement of the entire UK green crop drying industry (output approx 150 000 t/a is equal to only 5% of that produced when the surplus straw in a 'normal' year is burned in the field.

Whether or not whole crop harvesting is adopted commercially in the UK depends on many factors which include the long-term climatic trends, possible improvements in combines, and the largely unknown cost of grain lost to birds and through shedding. That interest in the system exists is confirmed by enquiries from countries with hot dry climates where the ripening/shedding period is uncomfortably short, and by the construction of a plant in southern Sweden which will commence operation in 1977 and have a seasonal capacity of 2000 hectares of cereals.

Bibliography

1 **Baker M J** (1968). Future development in the harvesting and handling of cereals in Britain. Unpublished Honours BSc dissertation, University of Nottingham.

2 **Owers M J** (1974). The utilisation of dehydrated crops by growing ruminants. Unpublished PhD thesis, University of Nottingham.

3 **Shamsham K I A** (1974). The mechanisation of harvesting, drying and processing whole cereal crops. Unpublished MPhil thesis, University of Nottingham.

Power take off driveline dynamics and overload protection devices for agricultural machinery

DA Crolla; A A W Chestney; T C D Manby *

Summary

PROBLEMS associated with the dynamics of pto drivelines are discussed and a method is outlined for analysing a tractor/machine driveline. Results are given of the performance of various friction materials in overload clutches.

Abstract

THE dynamics of agricultural pto drivelines have to date received little attention despite trends towards bigger, more powerful machines, increased use of 1000 r/min and front driven pto machines. In this paper, the problems associated with the dynamics of pto drivelines and methods of protection against overloads are discussed.

A method is outlined for analysing a tractor and machine driveline, both when starting and in work, using a simplified model. The effects of an overrun clutch, backlash and Hookes joints in the driveline are examined. Field measurements of torque loadings on a range of pto driven machines are also described. When analysis is completed, a comprehensive range of data will be available to define both the exciting torque inputs to the theoretical model, and typical services loading patterns.

The performance of existing overload protection devices has been summarised in a previous paper in this journal but more recent work, aimed at improving the performance of friction materials in overload clutches is presented. The effects of material combination, surface roughness, pressure, flatness and temperature on friction plate overload clutches are discussed. Suggestions for improving performance by grooving the friction material or using oil immersed materials are made.

1 Introduction

There have been four recent trends in agricultural pto driven machinery which have emphasised the need for a greater understanding of the dynamics of drivelines. Firstly, machine power levels have increased at a similar rate to mean tractor power levels. This has resulted generally in larger and heavier machines, but more important, in machines whose rotating parts have far higher inertias. Secondly, machines have increased in sophistication and more complex and expensive drivelines are required. Thirdly, operation at 1000 r/min is becoming more widespread. This has already caused wear and fatigue problems for such apparently simple devices as overrun clutches which were satisfactory for 540 r/min machines, and balancing of shafts to avoid vibration is more critical than at the lower speed. Fourthly, it appears likely that front-mounted power driven machines will find increasing usage. If the drive is taken from the front of a conventional diesel engine, then another expensive element, the engine crankshaft, is introduced into the driveline and both the driveline design and adequate overload protection becomes increasingly important.

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* *A paper based on this work was presented to SE Midlands Branch on 7 March 1977 at NCAE, Silsoe.*

Previous work on drivelines has not provided the depth of background knowledge necessary for machine and driveline designers. Hansen[1] in 1952 was one of the first workers to measure the high torques that occurred during rapid pto clutch engagement for a range of machines, including forage harvesters, balers, combine harvesters and hammer mills. The introduction by tractor manufacturers of fast response hydraulically engaged pto clutches prompted further interest as breakages during starts became more common. In 1975, Chestney[2] compared tractors having manual and hydraulically engaged pto clutches when starting a forage harvester and drum mower and conditioner. He found that peak torques of up to four times the mean working value could be imposed due to the sudden application of the hydraulically engaged clutch.

Measurements of torque during normal working are more common but usually these have been restricted to simple mean values to compare average machine work rates or throughputs. Both Pearson[3] in England and Kuhlborn[4] in Germany however have reported some torque measurements which included amplitude and frequency distributions of the loading patterns.

The overall picture therefore is one of individual investigations, but still no complete understanding of the more fundamental aspects of driveline behaviour. Progress in the subject has to some extent been hindered by the fact that tractor and machine manufacturers have often tended to work in isolation. In some cases one problem has been solved at the expense of another. For example, tractor manufacturers introduced hydraulically engaged pto clutches to avoid the wear problems of the previous manually engaged types but in doing so created other problems for machine manufacturers, by imposing higher peak torques in the driveline when starting. The obvious lesson to be learnt is that any attempt to investigate driveline behaviour must include the entire driveline from tractor engine to the final machine working parts. The objects of our work were therefore to provide an understanding of overload clutch driveline behaviour during both starting and normal working.

2 Simplified model of tractor and machine drivelines

The simplified model of a tractor and machine driveline, shown in fig 1, was used in the theoretical analysis. Several assumptions were made;

(1) The tractor engine and machine working parts can be replaced by equivalent inertias, I_e and I_m. This is justifiable for the tractor engine which is dominated by the flywheel inertia and machines such as drum mowers or forage harvesters where most of the inertia is concentrated in the final cutting parts. The model may need to be extended for machines such as balers where simplification to three inertias may be more realistic.

(2) The shaft inertias are negligible compared to the other inertias.

(3) The stiffnesses of all the components of the machine driveline, such as shafts, gears, chains etc are linear and can therefore be combined to give an overall equivalent stiffness. In practice, where belt drives or rubber elements are included in the driveline, a non-linear spring characteristic may be needed to simulate them.

The equations of motion of the simplified model are given in full in reference 5, and will not therefore be repeated here. They were used in a computer simulation model to examine performance (a) when starting the machine and (b) during normal working.

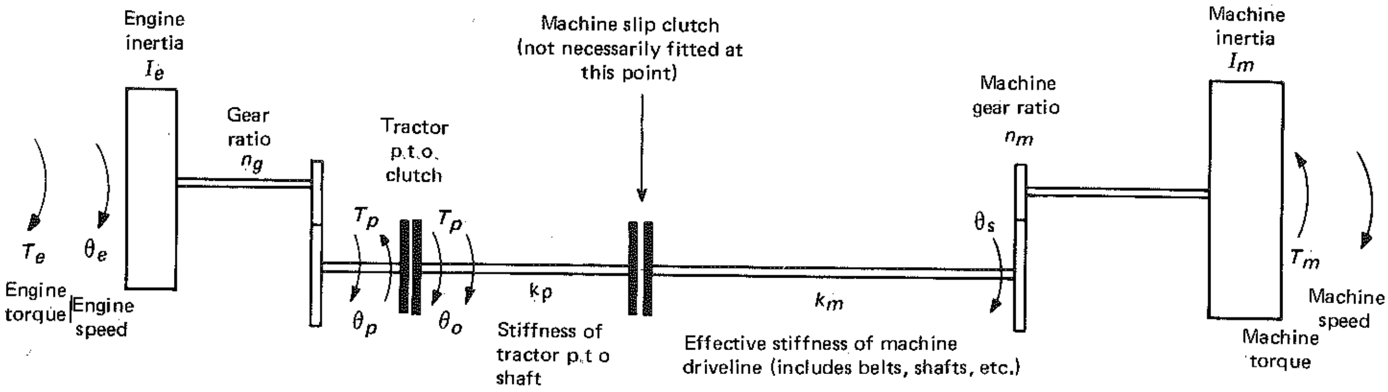


Fig 1 Simplified model of tractor and machine p t o. driveline

3 Starting high inertia machines

There are two critical components to be considered when starting high inertia machines; the tractor pto engagement clutch and the machine overload clutch. A typical characteristic of a modulating, hydraulically controlled pto clutch is shown in the upper graph in table 1. The parameter values vary with individual tractors; some have a modulated period of up to 2.5 s whereas other simpler designs have a nominally instantaneous engagement period, although it has been found that approximately 0.8 s is typically required to reach maximum torque.[2] The characteristic of an overload clutch is shown in combination D of table 1. If the driveline torque exceeds the breakaway torque of the clutch, then slip will occur until the driveline torque drops, when the clutch will take up the drive again.

Using data from a 52 pto kW tractor and a 2.3 m drum mower and conditioner, a series of simulated starts was carried out using six combinations of clutch characteristics shown in table 1.[5]

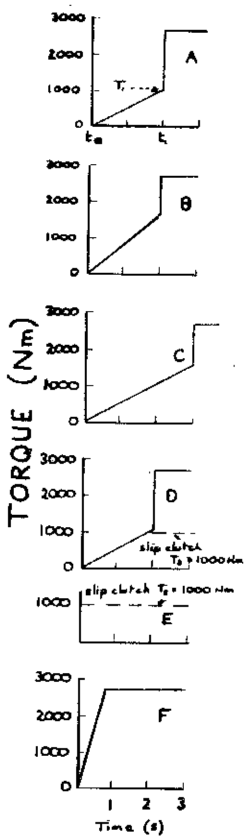
The details of the clutch characteristics were,

- A As shown in table 1
- B As clutch A, but T_1 = 1620 Nm
- C As clutch A, but $(t_1 - t_e)$ = 3 s, T_1 = 1620 Nm
- D Clutch A + overload clutch in driveline
- E Instantaneous pto engagement + overload clutch in driveline
- F Nominally instantaneous pto engagement clutch, $(t_1 - t_e)$ = 0.8 s but no overload clutch fitted.

Peak torques of approximately four times the typical mean working torque (700 Nm) are imposed in the driveline if there is no modulation of the pto clutch (clutch F) or if the modulation is not sufficient (clutch A). The peaks can however be reduced either by choosing the slope or the length of modulation period more carefully (clutches B and C) or by incorporating an overload clutch (clutch D), which prevents overloads even if the pto engagement is instantaneous (clutch E). The other information in table 1 gives details of engine

→ page 8

Table 1 Results of simulated starts



	Lowest engine speed, r/min	*Maximum driveline torque [min. in brackets], Nm*	*Clutch slip, rev*	*Time of clutch slip, s*	*Time to reach full pto speed, s*	*Total energy dissipated by clutch, J*	*Average rate of energy dissipation over slip period, W*
A	1100	2700 [−900]	18.5	2.2	4.3	64,400	29,200
B	1250	1570 [0]	15.5	2.0	4.0	61,200	30,600
C	1450	1380 [120]	20.5	2.5	4.3	70,200	28,000
D	1680	1000 [400]	pto 17.5 Slip 4 Total 21.5	1.8 1.1 2.9	4.3	53,000 20,600 73,600	29,400 18,700
E	1540	1000 [400]	8.5	1.7	3.4	56,500	33,200
F	800	2650 [−900]	5.7	0.8	3.5	39,200	49,000

speed, clutch slip, time for the machine to reach full speed and energy dissipated by the clutch.

Using this technique the designer can choose the necessary pto engagement characteristic with or without a machine overload clutch for a particular tractor and machine combination.

4 Torsional vibration during normal working

Using the same simplified model of fig 1, torsional vibration of the driveline was analysed by calculating the frequency response to a sinusoidal torque disturbance. Details of the equations are given in reference 6.

Using the same tractor and machine data as previously, the calculated response is that typically expected from a two degree of freedom system, with one natural frequency, in this case at 3.5 Hz. Since the damping ratio of the driveline is normally small, eg less than 0.1, large speed variations occur if the system is excited near its natural frequency. The driveline design therefore must avoid inputs from engine, machine working parts such as blades or tines, or Hookes joints which excite the system near its natural frequency. The overload clutch will not normally affect the frequency response unless the torque fluctuations are sufficiently large to cause clutch slip.

An overrun clutch however does affect the response, and for this example, the natural frequency may be halved in some operating conditions due to the discontinuous effect of the overrun device. It is possible to predict the frequencies at which the overrun clutch will affect the system knowing the mean torque, disturbing torque and system inertias.[6]

Most practical drivelines include some backlash due to small amounts of free play in couplings, gears etc. For example, the effect of including ± 6 deg of backlash in the simplified model has two significant effects. Firstly the overall level of speed variation over the entire frequency range is increased and secondly the natural frequency is changed to 2.5 Hz. Reference 6 describes in more detail the effects of various degrees of backlash and their relationship with the other system parameters. Space does not allow a more detailed analysis in this paper but the main point is that driveline behaviour is significantly affected by backlash and overrun, and an analysis of a practical driveline would be incomplete if they were omitted.

Nearly all pto driven agricultural machines include joints in the driveline to permit articulation between tractor and machine. By far the most commonly used is the Hookes or universal joint. Normally they are in pairs, and the equation relating input and output speeds is well known, assuming that the inertia of the connecting shaft can be ignored.

Using the same tractor and machine data, the effect of Hookes joints running at a total offset angle of 20° is shown in fig 2. Machine speed and torque variation are plotted against shaft speed. The frequency of the torque disturbance caused by the Hookes joints is twice the shaft speed, so it can be seen that when (2 x shaft speed) = 3.5 Hz, ie when the shaft speed = 105 r/min, the system is disturbed at its natural frequency. In this case the disturbing frequency at normal operating speed of 540 r/min is well away from the natural frequency, but the machine would pass through the whole frequency range during starting and would therefore be excited at its natural frequency for a short period.

5 Field measurements of torque loading patterns

A series of field measurements of the torque loading patterns of a wide range of pto driven machinery has also been carried out as part of this work. Torque was measured using a standard torquemeter initially and later using a strain gauged shaft which could easily be inserted in the driveline, with the signal transmitted by short range telemetry equipment. This had three advantages over the previous device, (a) it was shorter and therefore less alteration of shaft and linkage lengths was required, (b) it avoided any fixed attachments to the shaft and (c) it was lighter and caused less vibration at 1000 r/min operation. Overload clutch slip was monitored in cases where a clutch was fitted by photo-electric cells and interrupter plates on either side of the clutch.

The analysis of all the results is not yet completed, but the data should be available in an NIAE Departmental Note by early 1978. However it is worthwhile quoting examples from the results here to illustrate the basic aims of the work and its relevance to the theoretical analysis.

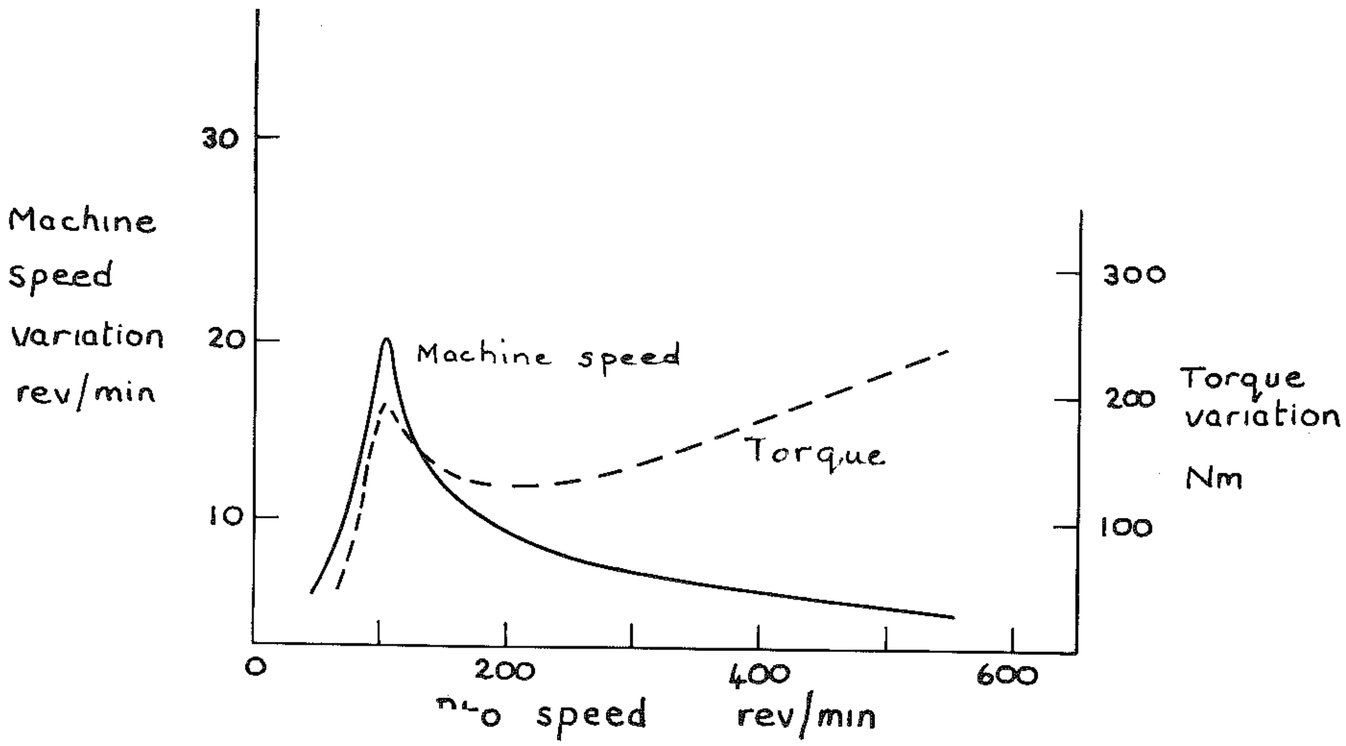
The examples chosen are from three different types of baler because they illustrate the vastly different loading patterns to which drivelines may be subjected. The upper diagrams in fig 3 show the torque traces recorded for, (a) conventional baler, (b) large cylindrical baler and (c) large rectangular baler.

The differences among the three are spectacular; the first and third balers show pulsating torque patterns corresponding to the ram cycle, with the cylindrical baler producing a less fluctuating torque. In the latter case, the variation at the end of the trace was due to the baler being operated while the tractor was turning, thus causing the Hookes joints to run at an increased angle.

The middle and lower graphs show the analyses of the corresponding baler torque traces. The middle graphs are amplitude analyses of the torque, which was sampled at 100 Hz and the percentage distribution of these samples over a 20 s period is plotted against torque. The mean, maximum and standard deviation are also shown and a simple assessment of the torque loading on the driveline can be obtained by comparing the ratio of the maximum to the

→page 10

Fig 2 Effect of Hookes joint on speed and torque variation in driveline.



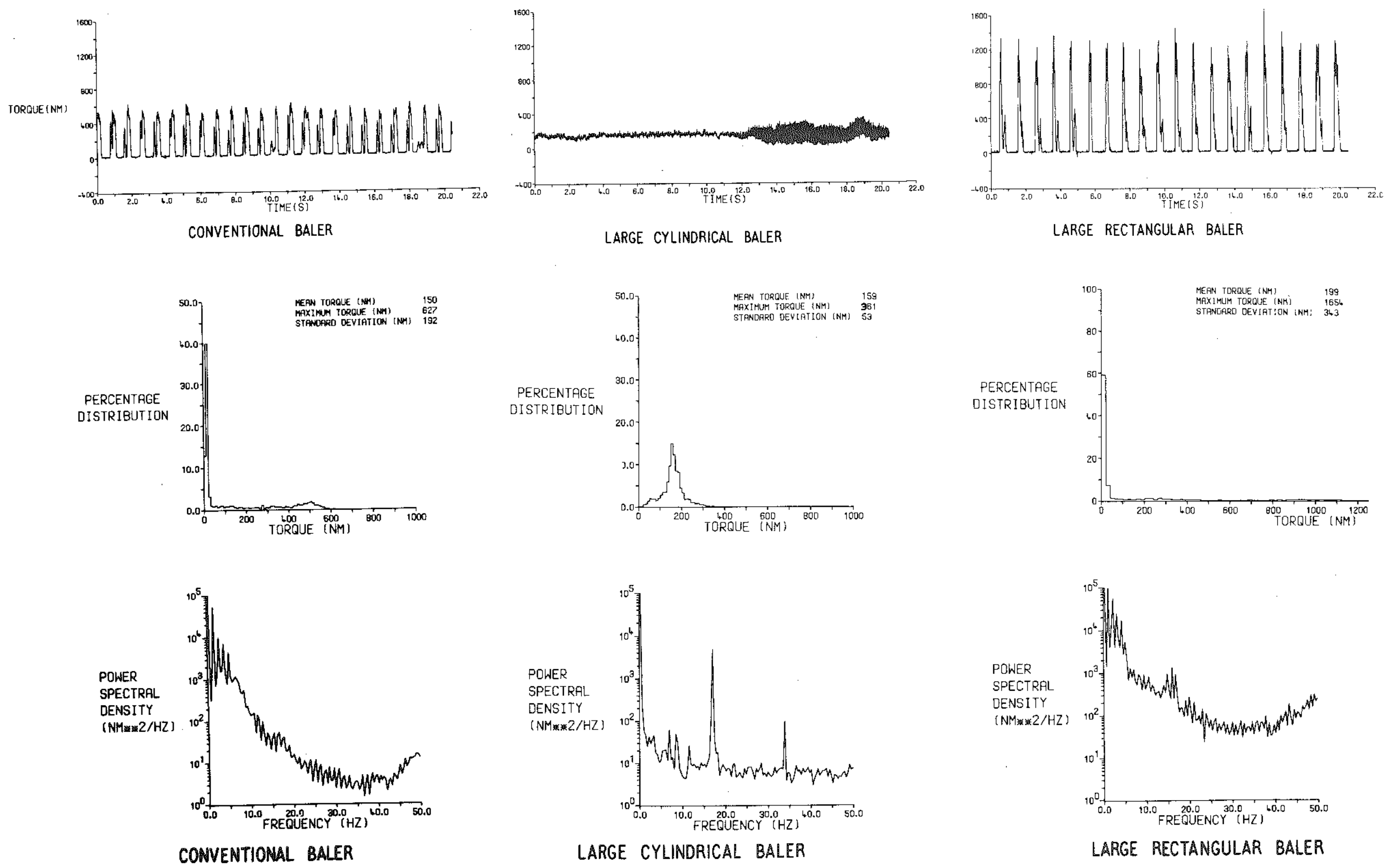


Fig 3 Results of torque measurements on three types of baler.

mean torque in each case. From left to right the ratios are approximately 4, 2 and 8.

The lower graphs are the corresponding frequency analyses, where power spectral density is plotted against frequency, and the main frequency components of the torque loading occur as peaks on these graphs. For the first and third balers, the main peaks are at about 1, 2, 3 and 4 Hz, which correspond to the main ram stroke frequency at 1 Hz in each case and multiples of it. For the cylindrical baler, the main peaks at 17 and 34 Hz are caused by the disturbing torque of the Hookes joints. The pto speed was probably slightly less than the standard 540 r/min, which would result in frequencies of 18 and 36 Hz but since the tractor engine speed was set using the tractor revolution meter, discrepancies of this order would be expected.

These results show quite clearly the differences in loading characteristic that can occur on different designs of a similar machine. Differences over a range of various machines are just as marked. It is hoped ultimately that these data will provide a comprehensive record of (a) torque amplitudes, and (b) frequencies of disturbing torques, for a wide range of machines in various conditions. For the machine designer, these data will be of direct benefit in quantifying the magnitude and shape of the machine torque pattern in typical operating conditions. For the overload clutch designer an amplitude analysis of the machine torque is of particular relevance since it specifies the number of overloads encountered per unit time. Further analysis of these data in future may provide information on fatigue life and failure prediction. The torque loading data also define the frequencies of the exciting torques which then enable driveline response to be predicted from the theoretical frequency response curve.

6 Overload protection devices

The performance of various types of overload devices used on pto driven agricultural machinery has been summarised previously.[7] In general, the performance of all the overload devices evaluated was inconsistent and breakaway torque values were spread over a wide range. However the performance of friction plate overload clutches was more consistent than plunger and ball ratchet types. Friction plate clutches also had the advantage of controlling the starting torque on high inertia machines whereas for plunger and ball ratchet types, the slipping torque was so low compared to the breakaway torque that the machine was not accelerated to working speed. The main disadvantage of the friction plate overload clutch is that it provides no warning that the clutch is slipping, and this can have practical difficulties when a machine fitted with an overload clutch is driven by tractors with excess power available. If the operator attempts to use more power than that for which the machine and overload clutch were designed, excessive clutch slip will occur and it was recognised that this problem would become more widespread as the operator becomes more remote from the machine. It may ultimately be necessary to incorporate automatic warning devices to alert the operator to overload clutch slip. However, since improvements in friction material performance would result directly in improved overload clutches, factors affecting the performance of friction materials were investigated in more detail.

Although much research has been carried out into friction materials for automotive and industrial applications, little of it is relevant to agricultural overload clutches where two special conditions apply. Firstly the material is permanently clamped up, whereas in other applications pressure will normally only be applied when the material operates. Secondly, when slipping the material always operates at maximum work rate whereas in other applications, such as automotive brakes or clutches, the material operates for most of the time with less than maximum pressure applied and hence less than its maximum work rate. The reason for the lack of research into overload clutches is that the volume of friction material involved is small in comparison with other applications and has not justified research expenditure.

6.1 Factors affecting friction material performance

The effect of the following parameters was investigated; (a) material combination, (b) surface pressure, (c) surface roughness, (d) flatness of ferrous mating plate and (e) clutch bulk temperature. The results are reported in detail in references 8 to 11, and the main conclusions are summarised below.

(1) One type of sintered metal friction material gave a more consistent performance than the organic materials tested and required less running in. Its static and dynamic coefficients of friction were also closer than the organic materials and this aspect is important in overload clutch applications where the clutch is required to drive the machine immediately after the clutch has slipped due to a temporary blockage.

(2) Coefficient of friction of the material combinations tested tended to decrease with an increase in contact pressure.

(3) Surface roughness had little effect on consistency of performance but to reduce wear the ferrous mating plates should have a surface roughness better than 1.25um.

(4) Although all tests were carried out with ferrous mating plates machined parallel to within 0.025 mm, clutch plates well outside this tolerance gave surprisingly consistent results which may have been due to their ability to allow wear particles to escape.

(5) Coefficient of friction tended to decrease with increasing surface temperature. However, some materials showed an increase in coefficient of friction as clutch bulk temperature increased and this may have been due to the combined effects of heat, wear particles and pressure modifying the material surface.

(6) Sintered material tended to adhere less to the ferrous mating surface than organic materials but further work is required to investigate the problem of adhesion more fully. A proposal to design a combined slip and overrun clutch which separated the mating plates every time it overran was investigated as a method of overcoming the problems of adhesion, but prototype designs to date have proved to be uneconomic. Further consideration is being given to this.

Although these results provide a sound base of design data for overload clutches, the most significant conclusion of these investigations was that coefficients of friction were always higher than the values expected in other applications, as shown in table 2. The increase for the organic materials, which was up to 140% in the case of material A was consistently greater than for the sintered metals.

Table 2 Comparison of measured and quoted values of static coefficient of friction

Material combination	*Static coefficient of friction* — *Nominal figure quoted by manufacturer*	*Measured on experimental rig after 1750 rev of clutch slip*
Organic material A/ cast iron	0.31	0.84
Organic material B/ cast iron	0.35	0.57
Organic material C/ cast iron	0.36	0.65
Sintered metal A/ cast iron	0.23	0.40
Sintered metal A/ mild steel	0.23	0.34

It was postulated[8] that these discrepancies were due to the unique conditions imposed by overload clutches, in that (a) the material is permanently clamped which prevents the escape of wear particles and (b) when slipping it always operates at maximum workrate.

To assist the escape of particles, radial grooving of the friction material was suggested as a method of improving performance.

6.2 Effect of grooving

Eight radial grooves were machined in organic friction material plates.[12] Both 2 and 8 mm groove widths were tried and the results of operating these materials in an experimental overload clutch were compared with previous results for ungrooved plates.

The narrow grooves tended to block with wear particles and were therefore ineffective. The wider grooves removed more wear particles and did not become blocked but on examination of the plates, some debris remained trapped and compressed on the rubbing area. Some improvement in consistency of coefficient of friction was measured for the wider grooved plates, but it was concluded that more grooves were necessary to ensure complete removal of wear debris.

Further work using more grooves and their effect on sintered metal materials is planned.

6.3 Oil immersed clutches

This work has highlighted some of the shortcomings of dry friction materials used in overload clutches. By providing a more controlled environment where the friction material is lubricated and sealed, it may be possible to improve consistency of coefficient of friction and reduce adhesion. Further work is planned with an oil immersed overload clutch, using paper based friction material and lubricants currently employed in the automotive industry, to examine whether

→page 12

a sufficient improvement in performance can be obtained to justify the extra expense over a dry clutch.

If an oil-immersed clutch performs satisfactorily it may be possible to incorporate an adjustable overload clutch in the tractor pto driveline and take advantage of the existing reservoir of oil for lubrication and cooling. It should be relatively simple, using hydraulic pressure, to arrange for the clutch slipping torque to be set to the correct value to suit any particular machine. However, the responsibility for setting the clutch would rest with the operator since machine damage could result if the incorrect setting were used. Although this approach may provide a technically superior solution to the problem of overload protection, there are obviously several practical difficulties involved which would limit its immediate acceptance. Nonetheless, as a long term solution it may offer advantages.

7 Conclusions

1 Recent trends toward bigger, more powerful and more sophisticated machines indicate that tractor and machine manufacturers will have to pay more attention to the problems associated with pto drivelines than they have done in the past.

2 A theoretical method of investigating driveline behaviour during starting and normal work is outlined. It is shown that suitable modulation of the tractor pto clutch or the inclusion of an overload clutch is necessary to prevent excessive peak torques during starting. The effects of overrun, backlash and Hookes joints all affect the frequency response of the driveline to torque disturbances.

3 Field measurements of torque loading patterns are providing a library of data on amplitudes and frequencies of the fluctuating torques imposed on a wide range of pto driven machinery. These data will be of direct benefit to overload clutch and machinery designers, and will be available from NIAE early in 1978.

4 Work to date, particularly on friction material performance, has provided the necessary data to optimise overload clutch design. Further work to investigate performance of grooved materials and oil-immersed clutches is planned.

Acknowledgement

We would like to thank K Cochrane for his helpful suggestions and assistance with the experimental work.

References

1 **Hansen, M.** Loads imposed on power take off shafts by farm implements. *Agric Engng* 1952 33 2.

2 **Chestney, A A W.** The measurement of starting torques on tractor pto driven machines with high inertias and the effect of using a torque limiter to control them. Dep Note DN/ER/592/1172, natn Inst agric Engng, Silsoe, (unpubl).

3 **Pearson, G.** An analysis of the torques imposed on the tractor pto by some hay and silage machinery. Dep Note DN/TE/085/1420, natn Inst agric Engng, Silsoe, 1971 (unpubl).

4 **Kuhlborn, H.** Torsional vibration of tractor and farm machine systems. *Grundl Landtech*, 1973, *23* (1) 2 and *23* (2) 41.

5 **Crolla, D A.** A theoretical analysis of inertia torque overloads when starting pto driven agricultural machinery. *J agric Engng Res* (1977) *22*, 197–208.

6 **Crolla, D A.** Pto drivelines for agricultural machines: III Vibration analysis of a simplified tractor machine model. Dep Note DN/ER/764/1172, natn Inst agric Engng, Silsoe, 1977 (unpubl).

7 **Chestney, A A W.** Overload protection for pto driven agricultural machinery. THE AGRICULTURAL ENGINEER, 1976 *31* (2) 27–33.

8 **Crolla, D A; Chestney, A A W.** The performance of friction material in overload clutches. (To be published in Wear, 1977).

9 **Crolla, D A; Chestney, A A W.** Overload clutches for agricultural pto driven machinery: I Performance of various friction materials. Dep Note DN/ER/765/1172, natn Inst agric Engng, Silsoe, 1977 (unpubl).

10 **Chestney, A A W.** Overload clutches for agricultural pto driven machinery. II A comparison of the performance of dry and impregnated sintered plates. Dep Note DN/ER/784/05005, natn Inst agric Engng, Silsoe, 1977 (unpubl).

11 **Chestney, A A W.** An investigation into various factors affecting the performance of slip clutches. II Further experiments to determine the effect of surface roughness on the running in characteristics. Dep Note DN/ER/702/1172, natn Inst agric Engng, Silsoe, 1976 (unpubl).

12 **Chestney, A A W; Crolla, D A.** Overload clutches for agricultural pto driven machinery: III Performance of organic friction materials with radial grooves, Dep Note DN/ER/810/05005, natn Inst agric Engng, Silsoe, 1977 (unpubl).

Reduction of oil consumption for grass drying

G Shepperson

Summary

A VISIT to France was organised by the BAGCD to study methods of reducing fuel and energy costs of drying green crops. Equipment which has been developed to re-cycle part of the waste heat from exhaust gases may save up to 10%; more complex equipment, which re-claims latent heat by condensing water vapour, may lead to a net energy saving of 30% or more. Capital expenditure is likely to be high partly because of the need to use high grade construction materials, such as stainless steel, and special attention must be paid to the disposal of condensate.

1 Introduction

THE British Association of Green Crop Driers has formed an Energy Saving sub-Committee to examine ways in which the amount of fuel consumed in grass drying can be reduced. Pressure to do this has arisen because of the present high cost of oil in relation to the sale price of the dried product, the forecast price increase of oil over the next decade and the expected decline in supplies towards the end of the century.

A visit was made to Northern France in September by members of BAGCD to study equipment being developed and installed to reduce the net energy requirement of green crop drying, and to assess its suitability, in technical and economic terms, for installation in the UK.

Following this visit details of the equipment which had been inspected, and also of parallel developments in Denmark, were outlined and discussed in a full session at the Association's Annual Convention in November[1].

This paper presents a summary of the developments which were studied on the tour and are taking place elsewhere.

2 Exhaust gas re-cycling and the use of waste heat

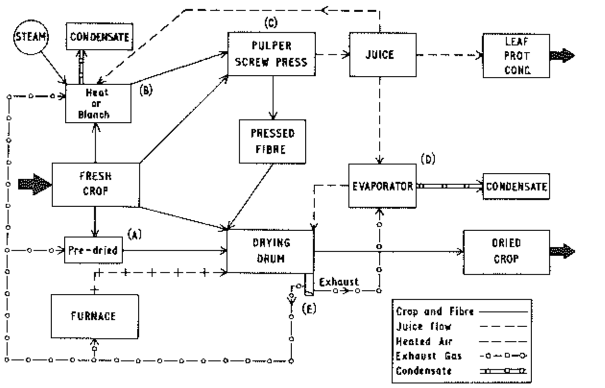
The use of a conventional drier to remove water from fibrous products such as grass or lucerne is relatively inefficient compared with the energy consumption required to remove water in industrial drying systems. The latter, however, use multiple stage evaporators, removing water under vacuum but they are too expensive and impracticable for drying farm crops, unless these are pre-treated by mechanical fractionation to separate water and dry matter. The various methods which can be used to treat the crop before it finally reaches the drying drum and to make use of the exhaust gases are summarised in table 1 and fig 1.

Table I

Exhaust gas	*Crop*
Re-circulate to furnace	Use heat from exhaust gas to:
Condense to recover latent heat	– pre-dry fresh crop – blanch/heat fresh crop – evaporate extracted juice
Neutralise condensate and use as a fertiliser	Fractionate – fresh crop – blanched crop Separate protein, carotene, xanthophyll from juice

Much heat is lost from ordinary driers in the exhaust gases,

Fig. I. Methods of Crop Treatment and Heat Recovery to Save Energy



where the ratio of the weight of water vapour to dry air is commonly about 0.3:1. Much of this heat can be removed by recycling the exhaust, (E) and even more may be obtained by condensing the water vapour in heat exchangers (B) or evaporators (D) to re-claim latent heat. The water content of the exhaust air must be kept as high as possible and the water to dry air ratio is likely to be 0.6:1 when 35% of the air is re-circulated[2,3].

A greater improvement in thermal efficiency can be obtained by removing moisture in a pre-drier (A) or by blanching the crop before drying (B), using energy from the exhaust gases. Mechanical conditioning (C), which separates the plant fibre and juice, enables total energy input to be reduced by treating these fractions separately. It is also a means of removing a very high quality part of the crop from the more fibrous bulk.

3 Grass drying installations fitted with energy saving equipment

3.1 France lucerne de-watering plant at Marigney le Chatel

The objective of developments at this plant is to make the maximum use of energy by separating juice from the fresh crop and concentrating it in a 2-stage evaporator, before adding it back to the pressed forage for final drying; heat is supplied by steam and exhaust gases and a proportion of the latter is also re-cycled directly to the furnace.

There are two 15 t evaporative capacity Van den Broek driers on the site. Fresh crop from the feeder (A) of one of these (fig 2), can be diverted to the pre-drying process, where it is blanched in a large tank (B) for 3 to 5 min, at about 85°C; recirculated juice is indirectly heated by steam, to avoid adding additional water to the incoming crop. The blanching ensures that the maximum amount of juice, containing a small percentage of dry matter and protein, is removed in the subsequent pressing operation. After screening and some separation the hot crop is squeezed in a Stord Bartz screw press (C) rotated at about 5 to 6 r/min; when input dry matter content is 18%, about 60% of the weight is removed as juice. Pressed forage of 27–34% dry matter, depending on the amount of water in the fresh crop, is passed directly to the drying drum. The juice is heated to 170°C under vacuum and passed through a 2-stage Weigand evaporator, (D) where some heat is obtained from exhaust gases. Concentrated juice (molasses) is fed on to the pressed forage for drying in the main drum. Condensate from the exhaust gases is neutralised and irrigated, using rain guns. Modifications have been made to the burner to control the amount of air consumed, so that 450g of water vapour are exhausted in 1 kg of gas (ratio, water:air 0.8:1).

This experimental plant has been in operation for only one year and there have been some problems with choice of equipment. In spite of this, however, it is claimed that there has been a total saving

→page 14

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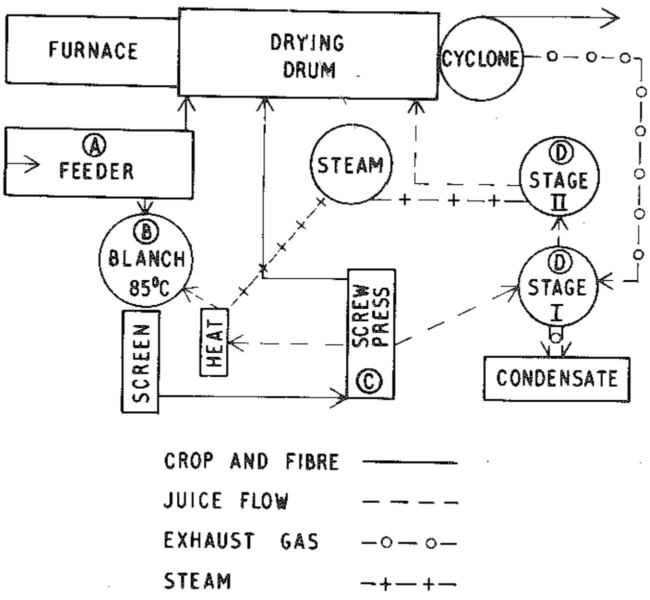
FIG. 2. DEWATERING PLANT FRANCE LUCERNE



of 30 to 40% in the specific energy requirement, after allowing for all additional inputs, including the provision of steam. For the same total oil consumption there would therefore be a commensurate increase in the production of dried lucerne. Full benefit can be derived from the potentially increased output because extra crop is available from the co-operating farms.

3.2 France lucerne fractionation plant at Mairy-sur-Marne

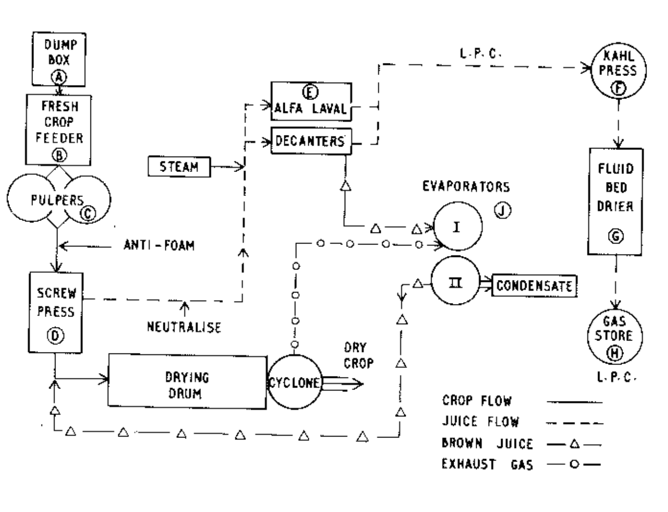
The requirement at this plant is to reduce the cost of oil per tonne of dried lucerne pellets, and to extract leaf protein concentrate (LPC) for sale, mainly as a pigmenting agent for broilers.

Two Van den Broek driers of 15 and 6 t/h evaporative capacity are installed on the site to service 1300 ha. The fractionation unit was being used to supply pressed forage to the larger drier; this was operating with an inlet temperature of 830°C and exhaust at 120°C and was capable of handling the total plant throughput of 40 t/h of fresh crop, as the effect of fractionation and exhaust heat recovery increased its evaporative capacity to the equivalent of 24 t/h.

Lucerne must be harvested throughout the day and night so that it is perfectly fresh when processed. It is loaded to the dump box (A) and conveyed via a feeder (B) to a battery of four horizontal pulpers (C) (fig 3). Juice is then extracted in a Speichim single-screw press (D) which has been developed especially for use with this plant.

Average dry matter of the incoming lucerne is 20% and this is increased to 30% in the pressed forage before it is dried. The addition of a small amount of an anti-foam re-agent before pressing appears to have eliminated juice foaming problems.

FIG. 3. FRACTIONATION AND PROTEIN EXTRACTION PLANT FRANCE LUCERNE



Protein is removed from the heated juice using two Alfa-Laval centrifuges (E). The LPC, with a dry matter of 50% is passed through a 2 mm die in an Amandus Kahl pelleting press (F) and is then dried on a fluidised bed drier (G) and loaded to a gas-tight store (H). Brown, or deproteinised, juice (DPJ) is concentrated in a 2-stage evaporator (J), the first of which is heated by gases from the main drier exhaust.

The output of LPC from a pilot plant, operated in 1975, was about 350 t in a season; during 1976, the first year of full scale operation, crop was in very short supply and so only 5.4% of the total lucerne throughput was obtained in this form. In 1977 however, during 2000 h of operation, over 1000 t of LPC have been produced, representing 7 to 8% of the total weight of about 15000 t lucerne pellets. The immediate target is 10% and it is expected that from 10–12% will eventually be obtained. Protein content of the dry matter of lucerne pellets made from pressed forage is reduced by about 2.5% and the xanthophyll and carotene content of the LPC, required as a pigment, is 1500–2000 mg/kg.

Costing so far shows that 49 g oil have been required per kg of water evaporated, ie about 50 l/t, (compared with a probable consumption of about 72 g/kg for normal drier operation). The additional cost of electrical energy for the whole system is 8–12 kWh/t of wet crop, which increases the energy cost/t of water evaporated by only a small amount. Sale price of the LPC is four to five times as much as the dried pressed fibre.

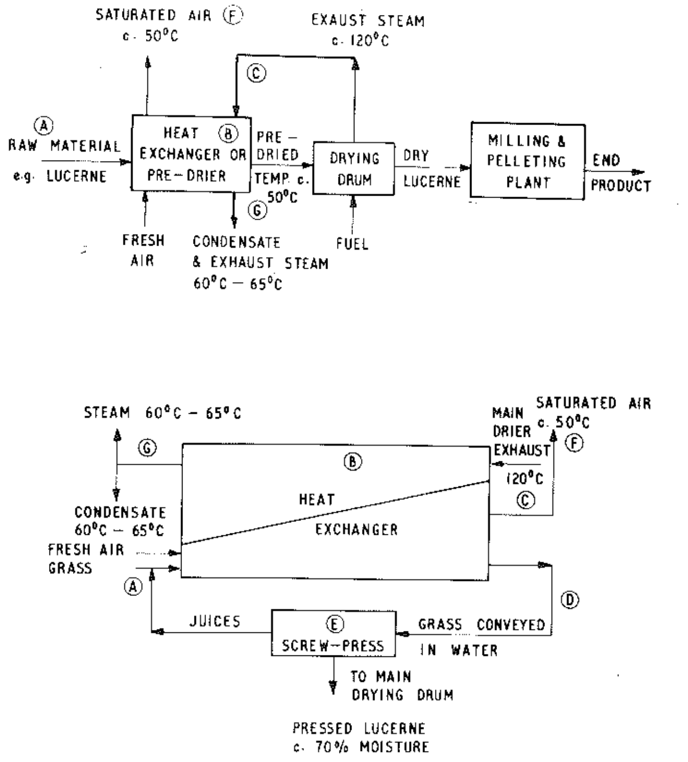
3.3 Swiss Combi heat re-cycling unit at Rafadin, Pocancy

The purpose of this equipment is to recover exhaust heat and use it in a pre-drier to condition fresh crop, before pressing it to expel juice. Direct re-cycling of exhaust gases to the furnace is also used, to help improve overall efficiency[4].

The installation is matced to a 20 t/h evaporative capacity drier; recent modifications have improved performance and simplified control.

Crop is harvested from 0400–2200 h and is tipped to storage heaps in the normal manner. For maximum efficiency it is essential to maintain the correct balance of the amount of juice extracted, and to do this a wet crop is required; hence field wilting is not possible. The intake from the feeder is split, which allows crop to be passed to both drier and pre-drier to facilitate starting up and enables adjustments to be made to control the juice level. Lucerne, or grass, is mixed with hot juice and conveyed through a pipe (A) to the heat exchanger (B) where it is heated by the incoming exhaust air (C) to approximately 80°C (fig 4). It is then passed over a vibrating screen (D) to remove excess juice and is squeezed in a single-screw press (E) to reduce moisture content by at least 5–7%. This pressed forage, with a moisture content typically of 70%, has a

FIG. 4. SWISS COMBI HEAT RE-CYCLING UNIT



temperature of about 50°C at entry to the drier, compared with a normal crop temperature of 20°C; it is estimated that this difference alone accounts for about a 4% energy saving. Excess water is exhausted from the crop at about 50°C (F), as it flows through the acid resistant stainless steel heat exchanger; exhaust gas from the main drier, which enters the pre-drier at 120°C, is expelled, together with condensate at 60–65°C (G). The latter has a pH of about 2.5 and it is neutralised with ammonia before storage and eventual distribution to the land. Although ammonia is less satisfactory than sodium hydroxide it has an advantage because N can be recovered as ammonium sulphate for crop growth. It has been calculated that 30 t of fertiliser can be produced per 1000 t heavy fuel oil used. As the condensate will have a high BOD value, it cannot be disposed of directly to waterways; care in distribution should create no real problem, however, compared with slurry or silage effluent, where BOD levels frequently exceed 30 000 ppm.

Re-cycling of exhaust gases is required for maximum efficiency and dew point must be as high as possible, eg 80°C. It has been claimed that a consequently lower oxygen concentration in the drying drum leads to less burning of the crop, but this is now thought to be an academic point. The observed advantage of less scorching in the drier probably arises from the breaking down of leaf and stem during the pre-conditioning process; because moisture within the macerated crop is evenly distributed drying takes place more evenly and so there is little loss of dry matter and protein.

Some difficulties have been experienced with short lucerne because the screen at entry to the press is not recovering enough juice. Problems arise if the quantity of juice does not correspond with the amount of evaporation from the pre-drier. Accurate control of the juice level is vital for efficient operation and so there are various ways in which this can be adjusted to match moisture content of the fresh crop.

Overall results indicate that when used with a drier of 20 t/h evaporative capacity the performance of the plant is equivalent to a 30 t/h unit, but with a saving of 500–700 1 of oil an hour. The energy required per tonne of dried crop can therefore be reduced by 30 to 40% by pre-conditioning. One added advantage of this equipment is that the method of recycling absorbs a great deal of dust from the exhaust air and cyclones and so reduces pollution; an original plan, however, to add back fines filtered from the flue gases caused problems in pelleting and so this procedure has been abandoned.

Capital cost of the heat exchanger is slightly more than the cost of the comparable drier, but it is thought that the investment could be saved in about 3 years of operation.

3.4 Van den Broek heat re-cycling unit, at Aulnay, Brienne-le-Chateau
The aim with this unit has been to devise a simple and comparatively inexpensive method of re-claiming waste heat from exhaust gases, which can give enough saving to cover the necessary capital expenditure within three years. It is installed on a Type ES 60 drier, which has a nominal evaporative capacity of 6 t/h.

About 30% of the exhaust air from the main fan, at a minimum of 95°C, is re-cycled through a lagged pipe of 800 mm dia, (A) from the main fan to the end of the furnace near the drier (Tertiary air) (B) and passes between the inner and outer skin to the burner end (C), fig 5. Neither the diameter of the exhaust stack, nor the exhaust temperature, of 96–110°C, have been altered for the installation. A small furnace, (D), within the body of the main unit has been built to ensure complete combustion of the oil before it is mixed with the tertiary air, (E), and this is regarded as the key to the success of the plant. It helps to prevent the outer bricks, which are no longer cooled by secondary air, from collapsing. An extra fan for the provision of secondary air, (F), is installed to add enough oxygen for combustion, as this is likely to be at a low level in the re-cycled air.

At a furnace temperature of 900°C the drier evaporative capacity is increased to 6700 kg/h. In a test with sugar beet pulp, containing 82–83% mc, specific consumption of the unmodified drier was 3.24 MJ/kg H_2O evaporated; modifications to the furnace reduced this figure to 3.09 MJ and the addition of heat re-cycling lowered it to 2.89 MJ/kg.

Hence an economy of at least 5% can be expected from the furnace modification with a further 6% from re-circulation; in fact an overall reduction of fuel cost of 13–15% is believed to be possible, but only 10% is guaranteed.

Cost of the complete re-cycling installation is about £20 000, including new brickwork, but if this is not required it is expected to be about £12 000.

Total annual output of this drying plant including beet pulp is 11 000 to 12 000 t and with lucerne 15 t/ha of dry matter is obtained from 450 ha; sale price of the latter was 64c/kg (£75/t).

3.5 Promill/CNEEMA heat re-cycling unit at Ablis
Exhaust gas is used to pre-dry the crop before it is passed into the main drying drum. At present quarter scale experimental equipment, developed in association with research workers at CNEEMA, Antony, is installed with a S900 drier of about 3 t/h evaporative capacity. One-third of the exhaust gases, at 90–100°C, are re-cycled from the main fan (5) directly to the furnace (3). One-quarter of the exhaust gases are washed in a tower (7), by spraying re-cycled water into the steam, and about half the exhaust vapour is condensed. Water at a temperature of 55°C is pumped to the pre-drier (2) where the heat from it is drawn by a fan through the incoming wet crop. Cooled water is returned at a temperature of 45–50°C and again washes the gases as they leave the main drier. At the present time the pre-drier is a modified horizontal pellet cooler but it is envisaged that it will take a different form in a full scale unit. The residence time for grass in the pre-drier is about 4–5 min, during which time the temperature of the incoming crop is raised from 20 to about 25°C. Grass moisture content is reduced from 80 to 75% and the total water removal capacity of the present unit is from 300 to 350 l/h. To enable the plant to run efficiently a diesel engine driven electric generator has been installed to cope with the increased load; 25 kW are required per 1000 kg of water evaporated by the pre-drier.

The plant had been in operation for about two months, during which time it had done 75 h of work. The washing tank was cleaned after about 50 h and it is expected that with full scale equipment this might be necessary every 200 h. Crop with moisture contents from 90% down to 60% can be dried and it has been calculated that fuel consumption may be reduced by up to 35% per ton of dried crop. Re-cycling alone, which has already been installed on several driers in France, is expected to give an 8–9% saving at a furnace temperature of 500°C and a 5–6% saving at a temperature of 800–900°C. In the full scale plant further improvements in efficiency are expected from lagging the flow of water to the heat exchanger. Because the exhaust gases are washed they are free of dust and smell and hence pollution is substantially reduced. Condensate from the washer is neutralised and spread on the fields.

→page 16

FIG 5 VAN DEN BROEK HEAT RE-CYCLING UNIT

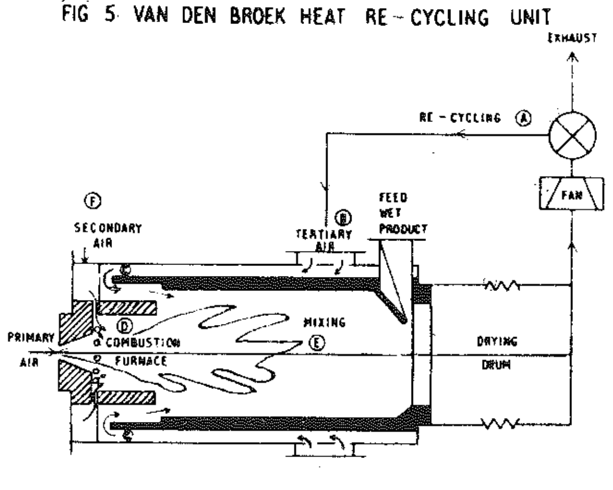
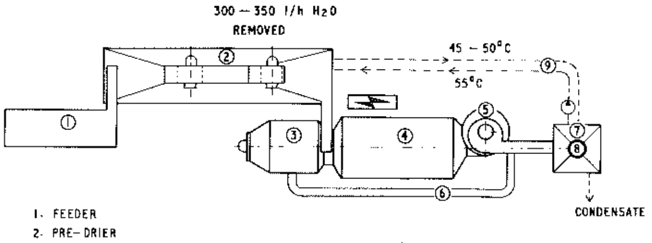


FIG. 6. PROMILL / CNEEMA HEAT RE-CYCLING UNIT



1. FEEDER
2. PRE-DRIER
3. FURNACE
4. MAIN DRIER
5. CYCLONE
6. EXHAUST GAS RE-CYCLING
7. WASHER AND WATER HEATING UNIT
8. EXHAUST
9. HOT WATER CIRCULATION PIPES

Table 2 Savings and costs of energy saving plants, assuming no increase in output of dried crop

Installation	*Method of heat recovery*	*Reduction in energy requirement†* %	*Reduction in energy requirement†* l/t(10% mc)	*Reduction in cost/t(10% mc)**	*Capital cost*	*Capital write-off period (15% interest)*
Van den Broek (6 t/h)	Exhaust re-cycling	10 – 13	27 – 35	£1.50 – £1.90	(a) £12 000 (b) £20 000	2–3 yr 4–7 yr
Combi 20 t/h	Exhaust re-cycling Latent heat recovery Blanching/pre-drying Screw pressing	35	95	£5.25	(a) £150 000 (b) £250 000	3.5 yr 7.5 yr
Promill 20 t/h	Exhaust re-cycling Latent heat recovery Pre-drying	35	95	£5.25	£235 000	7 yr

† Assumes 80 l oil/t water evaporated, 80–10% mc. **5.5 p/l oil*

It has been calculated that the total investment cost for a drier of 20 t/h evaporative capacity will be about 2M fr (£235 000) and a complete installation, including the drier, would be about 3.5M fr (£412 000).

4 Discussion

Most high temperature grass driers of acceptable efficiency require an input of 3.15 – 3.26 MJ/kg of water evaporated, depending on the type and moisture content of the crop. Hence to dry from 80% to 10% moisture content requires at least 275 litres of oil per tonne of dried crop. The total water vapour exhausted to atmosphere, however, contains nearly 8000 MJ of energy in the form of latent heat of evaporation, which can be equated to about 200 l of oil. Most of the equipment designed to recover this waste heat from drier exhaust gases is either experimental or is still being developed for commercial installations.

The simplest systems of heat recovery, involving re-cycling of exhaust gases which are mixed with incoming primary and secondary air in a modified furnace, is now available for Van den Broek driers; they guarantee an advantage of not less than 10%, eg a reduction in net specific energy consumption from 3.15 to 2.84 MJ/kg. Hence 71 l/t of water evaporated are required compared with 79 previously, and the oil consumption per tonne of dried grass is reduced to 248 l, a saving of 27 l/t under standard conditions. At a capital cost of £12 000 – £20 000, including furnace modifications, the individual operator can calculate his own total savings based on his own oil costs and assuming either the same or an increased output of dried crop. Probable cost reduction and capital write-off period for one set of conditions are shown in table 2; to break even it will be necessary to dry nearly 3000 t annually for a three year period.

All the other systems studied, based on energy saving alone, not only attempt to recover more heat by condensing water vapour; but also use the heat to condition the crop before it is fed to the main drying drum. In this way the amount of heat required to remove water can be reduced by 30 to 40% eg to a net 2.10 MJ/kg or less, leading to an oil saving of 80–110 l/t of dried crop. Such a saving amounts to £5 to £6.60/t for larger operators, but is accompanied by a high capital investment in rather complex industrial type of equipment.

The Combi system has already been installed on several driers. To increase efficiency of water evaporation the crop is indirectly heated by exhaust air in re-cycled juice and is then mechanically screw pressed to separate further juice from fibre; dry matter in the juice is contained within a closed circuit and recovered. Maintaining a balance between the rate of fresh crop input and the amount of juice is very important for optimum working, and this seems to offer the biggest problem to the drier operator. The saving in fuel cost is potentially much greater than can be achieved by exhaust gas re-cycling alone, but it requires a capital investment, equal to or greater than the cost of the original drier.

The experimental plant developed by France Lucerne uses a similar principle, of blanching and screw-pressing the fresh crop to remove juice and to evaporate water using exhaust heat, but it also requires the input of steam. Reduction in the total energy requirement, including steam production, appears to be similar.

It is interesting to compare the performance of these plants with the similar claims made for energy saving obtained with equipment developed by Atlas in conjunction with the Bioteknisk Institute at Kolding, Denmark. Re-cycling alone may reduce specific fuel consumption by 10% but this is considered inadequate to meet the needs of the industry. By removing half the drying load in the rotary drum and the remainder in a 2-stage vacuum evaporator it is expected that specific energy consumption can be reduced from 3.15 MJ to less than 1.58 MJ/kg of water.

A different approach has been developed by Promill, in association with CNEEMA, Antony, in which the crop is not pre-conditioned mechanically, but is heated and partly dried, using exhaust air and a hot water heat exchanger. As this plant is at present only a quarter scale installation further data will be needed before a realistic assessment can be made of operating problems and installation costs.

Fractionation of the fresh crop and recovery of very high quality protein and pigments for use with non-ruminants is an entirely separate process from those which seek only to save energy. However, there is an important common factor in the use of exhaust heat to evaporate de-proteinised juice before adding it back to the pressed forage for drying.

Installations of the type discussed may be required in many countries merely to reduce the amount of oil or gas used in the production of dried grass and lucerne, and in France operators are encouraged by the provision of substantial grants, as high as 40%. Because of the high capital input there will not therefore necessarily be any extra return, and with existing driers the overall result may be only a lower cost of fuel per tonne of output. Where output can be increased, as at the France Lucerne dewatering plant, it is possible that the total capital cost per tonne may also be reduced.

For new operators however the main advantage of heat recovery systems may be in the installation of a primary drying drum with an evaporative capacity lower than would otherwise be needed, eg a drier of 10 t/h could be purchased to cope with a nominal drying load of 15 t/h.

In considering the various types of energy and cost saving equipment, operators in the UK should not overlook two important points. Firstly, the initial drying load, and therefore fuel consumption, can be reduced by 30–50% by field wilting, for a comparatively small increase in field costs, provided the standard of harvesting skills and management are high. For this reason it may be desirable to link any further methods of fuel economy to a system which will operate efficiently with wilting. Secondly, as oil and gas become more expensive and scarce it may be possible to use an alternative fuel, such as coal. Apart from the favourable supply position into the forseeable future, the basic cost per unit of heat may be only 60–70% of the cost of oil eg £12.40 against £17.50/t when drying from 80–10% mc. As with heat re-cycling units, however, the ultimate decision will depend on the successful development of easily operated trouble free equipment suitable for grass drier input temperatures and having a capital cost commensurate with throughput.

The combination of crop dewatering, fuel economy and the production of high quality protein still seems to offer substantial benefits to the industry but at present the process seems likely to require an unrealistic level of capital investment for the cash return available in the UK from leaf protein concentrate.

References

1 **Shepperson, G.** Energy saving – some lessons from the Association study tour to France. *Grass*, 20, 9–14, 1977.

2 **Damborg, L; Mogensen, S N; Israelsen, M.** Drying alfalfa with low energy consumption, less air pollution. *Feedstuffs* 48 (45): 21–22, 1976 (Nov 1).

3 **Christiansen, C V.** Sammenkobling af roggasinddampar og tørreanlœg Rept. Bioteknisk Institut ATV Kolding, 1977. 18, 1 and 2, pp 14–18 (Danish).

4 Kunz, W. Heat recycling at the drying plant. Grass, 15, 31-34, 1975

A forage moisture meter - development and evaluation

R West

Summary

THIS paper summarises the development and characteristics of an instrument which measures moisture content of forage by electrical means. The magnitude is determined of two electrical parameters of a cell containing the material in question. Subsequent interpretation of these two values, by a simple slide-rule method, enables the moisture content of the material to be established.

Introduction

A MEANS of establishing the moisture content of forage crops has long been an important requirement of the agricultural industry. The chemical and physical changes caused by various amounts of water in crops during storage are complex and are not examined here. However, subjective assessment of the situation clearly points to the need for an instrument which will measure the moisture content of crops *before* they are committed to store. Moisture content is in fact a main consideration in deciding the storage fitness level — to coin a phrase.

The generally recommended levels of moisture content for different methods of forage storage are summarised in the following table:

Table 1 Recommended moisture content values for forage storage

m.c. %	*Crop and storage method*
Hay	
up to 15	Leafy immature hay for immediate storage.
up to 20	More mature hay for immediate storage.
20 to 25	For field stooks.
up to 25	Large bales or stacks for leaving in field.
up to 30	Propionic acid treated hay for immediate storage.
up to 40	Hay for artificial drying.
Grass silage	
45 to 55	Bottom unloaded oxygen limiting tower (N America).
55 to 65	Bottom unloaded oxygen limiting tower (Europe).
* 55 to 65	Top unloaded tower.
60 to 75	Sealed clamp or bunker. Wilted crop.
75 to 82	Open clamp or bunker. Unwilted.
Corn silage	
45 to 55	Oxygen limiting tower (N America).
up to 75	Oxygen limiting tower (Europe).
* 60 to 72	Top unloaded tower.
60 to 72	Sealed clamp or bunker.
High moisture corn	
25 to 32	Shelled corn (maize) (N America)
30 to 37	Ear corn (N America)
Dried grass	
8 to 12	

**Precise levels vary with silo size-grouping and manufacturers should be consulted.*

Basic considerations

Most attempts to measure moisture content by electrical methods have proved unsatisfactory because of the heterogeneous nature of forages and the wide differences in the physical characteristics of the materials themselves. (Compare Lucerne, Perennial Rye Grass and Red Clover).

However, the high dielectric constant of water (approx 80) appeared to provide a useful basis for an instrument. Indeed several earlier attempts by other workers to design an instrument had used capacitance measurement as a basis. Hence the variation of capacitance with water content within various materials was examined, at several different frequencies of supply emf.

It was observed that, although a general increase of capacitance with water content was apparent at all frequencies, this relationship was not identical for different materials plotted on the same graph. Also small percentage increases in water content gave rise to large increases in capacitance particularly at high moisture contents.

Figure 1 shows the relationship between the logarithm* of capacitance and the % moisture content of forage measured at a supply frequency of 30 kHz. The scatter of the results is to be noted. Similar results were achieved with frequencies up to 10 MHz. It was observed that scatter was appreciably greater below 30 kHz.

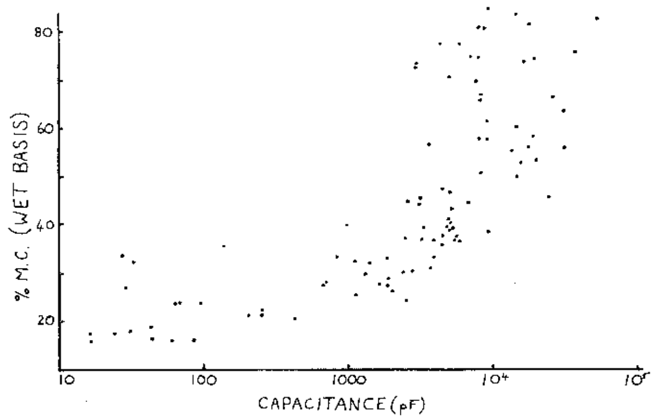
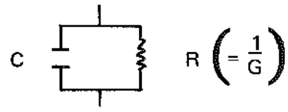


Fig 1

A means of improving the uniformity of the measured value was clearly desirable and the well known dependence of electrical resistance upon moisture content was brought into consideration.

A capacitive cell containing a "leaky" dielectric can be considered as having the equivalent circuit



where C is the cell capacitance and G is the conductance of the moist dielectric.

Measurement of the parallel conduction component revealed that the scatter of the capacitance results was greatly diminished if only a limited range $\frac{C}{G}$ was considered.

Figures 2 a, b, c show plots of $\log_{10} C$ against moisture content for several ranges of $\frac{C}{G}$

We have three variables in C, G and % moisture content and by measuring C and G the moisture content can be inferred using the above charts (or another, organised using different axes ie C against G). By compressing both C and G to take account of the wide dynamic range of both ie six decades, and plotting one against the other for moisture contents over the range 12% to 85% a chart can be evolved to extract moisture content from these two parameters.

It was quickly realised that a sample giving a high C and high G might have the same water content as one giving a low C and low G. It was observed that fresher samples fell into the latter category whilst those which had been stored for a period after cutting fell

→page 18

*The logarithm (base 10) was used in order to compress the scale and facilitate visual analysis of the plot.

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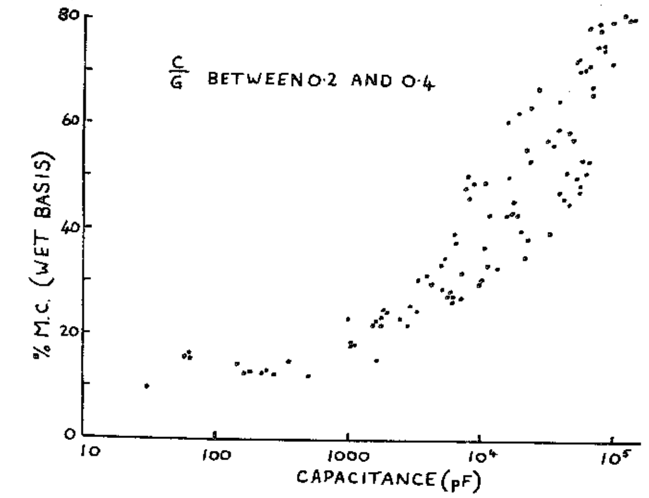
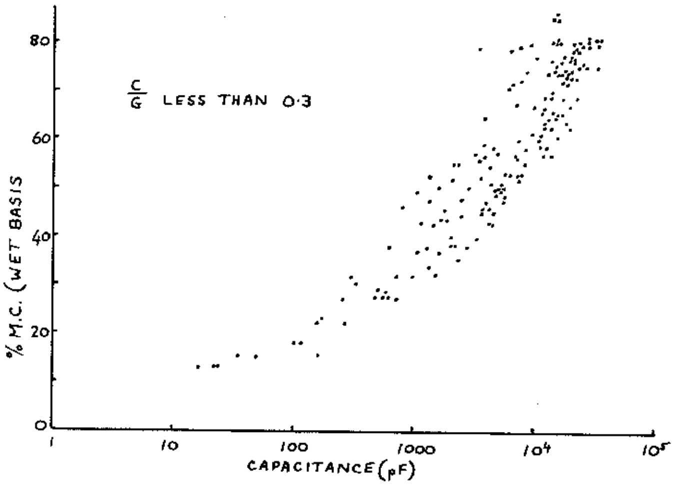


Above: Fig 2a
Below: Fig 2b



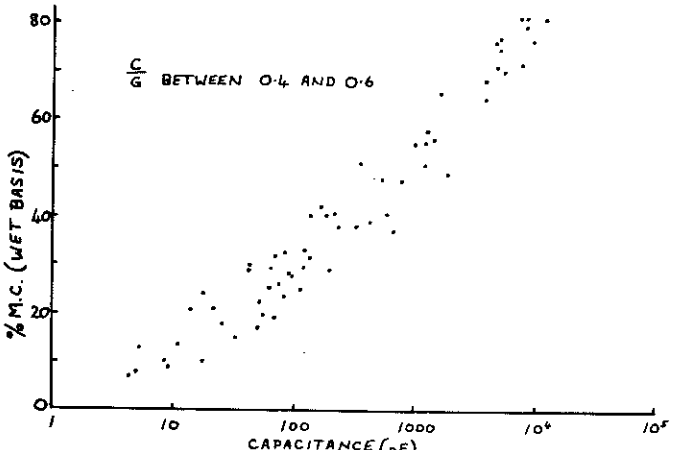


Fig 2c

into the former. The variation of the electrical parameters appears to be a function of the amount of 'bound' water ie that water which is contained within the cellular structure of the material. If the water is free and near the surface of the material it constitutes more freely available conductive paths between electrodes and also constitutes subsidiary electrodes to increase the effective capacitance.

The idea is somewhat empirical but it has held good over many thousands of practical measurements so far.

Compensation for varying sample sizes

The cell in which the early measurements were made comprised a cylinder with a fixed electrode at the base and a piston forming the top electrodes.

The measured values of C were modified to take account of varying sample sizes (inter-electrode spacings). The values were normalised to a spacing of 6 mm by scaling the reading up or down according to the interelectrode spacing. The cell diameter was 40.6 mm. The value of capacitance at 6 mm spacing with no material inserted was 1.9 pF.

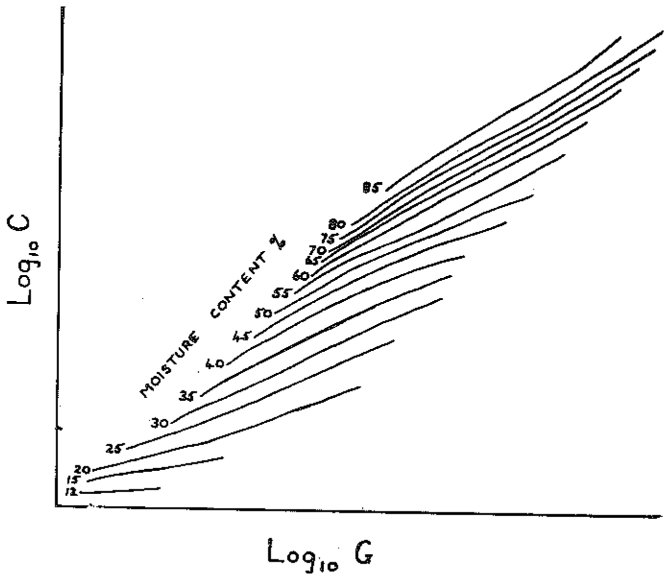


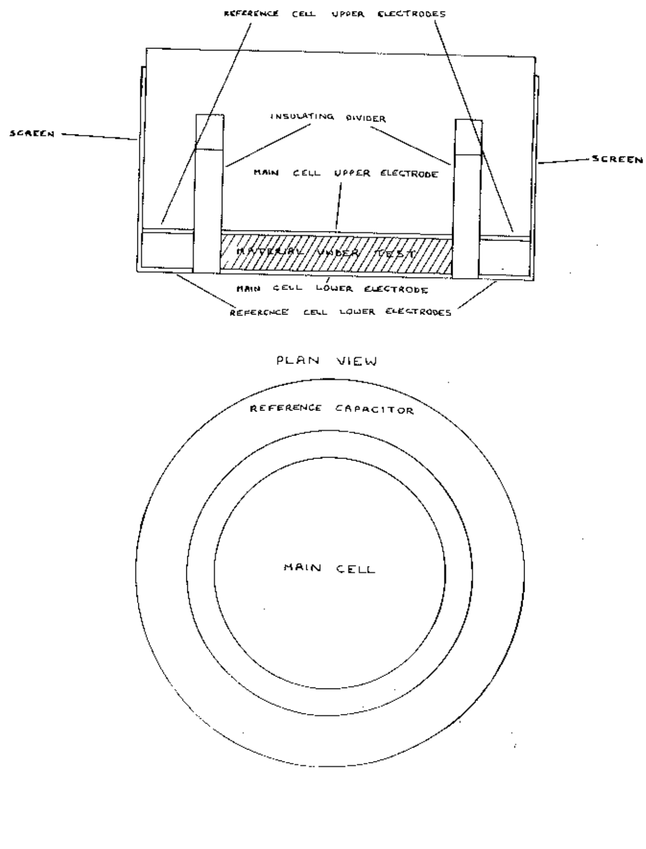
Fig 3

In the practical instrument a scheme of automatic compensation or normalisation was devised to make each measurement very quick and simple, obviating the need to measure vólume or weight. This comprised a pair of reference electrodes which were circular and concentric with the main cell. The upper electrode moved with the piston at the same height as the piston electrode whilst the lower reference electrode was fixed to the same base as the lower electrode of the main cell. The resultant capacitance between reference electrodes was used automatically to scale the main cell capacitance or conductance to give a normalised readout, in both cases according to the following equation:

$$\text{Normalised C} = \text{Capacitance at 0.6 cm spacing} \times \frac{\text{Main cell capacitance}}{\text{Reference capacitance}}$$

$$\text{Normalised G} = \text{Capacitance at 0.6 cm spacing} \times \frac{\text{Main cell capacitance}}{\text{Reference capacitance}}$$

Fig 4



Early results

Using approximately 200 results taken on various materials – Perennial Rye Grass, Italian Rye Grass, Lucerne, Clover, mixtures of grasses, Whole Crop Maize and Silage the chart fig 3 was compiled. The absolute moisture content of each sample was determined by oven drying at 110°C for 8 hours.

Further samples were measured and the inferred moisture content was extracted using C and G from the chart. These results were compared with the absolute moisture content by oven drying methods.

In a batch of 285 results the following accuracies were observed.
51% within ±2% mc of oven dried sample
85% within ±5% mc of oven dried sample

It was considered that the results were sufficiently encouraging for this path of development to be pursued.

Two areas of potential improvement were considered:

(a) Sample size. By increasing the volume of the main cell the effects of small local wet spots would be reduced. The area of the cell was increased by a factor of 14.

(b) Segregation of certain materials. The practical results varied from crop to crop ie legumes gave different C/G/mc characteristics from those of grasses, and ensiled crops were different again. By constructing different charts for these various categories, a greater degree of accuracy was possible.

Electronic development

The electronic design has five main features:

(a) *Synchronous detection*
To measure capacitance and conductance individually and independently.

(b) *Phase Lock loop arrangements*
To ensure frequency stability and synchronism.

(c) *Signal Compression*
To accommodate the wide range of signal input ie 1 000 000: 1 and to ensure a usable output scale

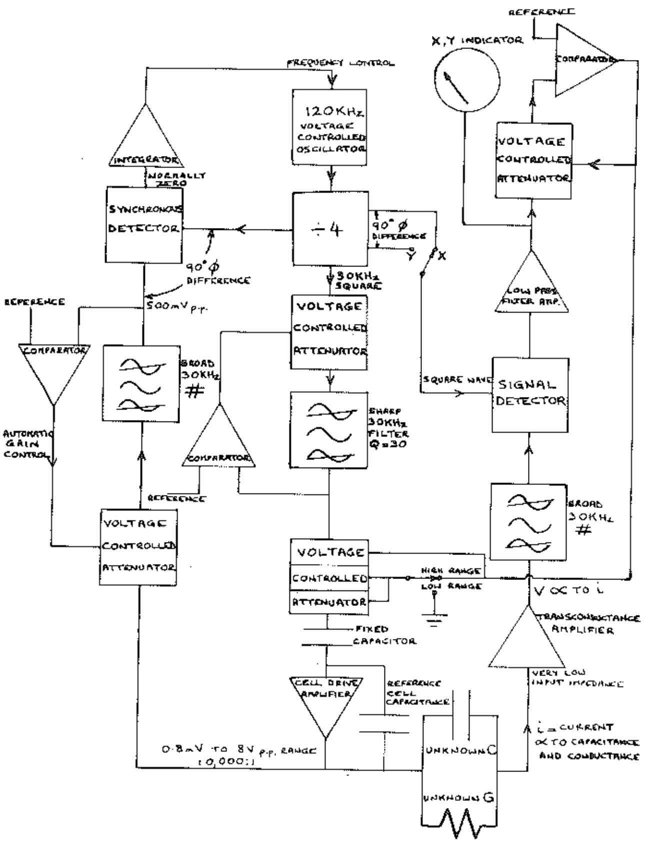
(d) *Automatic scaling as a function of reference cell capacitance*
This is done by varying the gain of an operational amplifier, using the reference capacitance as the feedback element, and using the output voltage to derive the capacitance and resistance of the material under test.

(e) *Balance of thermal effects*
To eliminate distortion due to thermal changes the system comprises balanced loops ie the phase lock loop section is balanced by the equivalent sections in the output loop such that a degree of 'tracking' is achieved.

The block schematic diagram is illustrated below in fig 5.

Fig 5 Forage meter electronic schematic diagram

This schematic diagram is of the circuit currently employed and includes the improvements made as a result of the 1975 field trials.



1975 field trials

Twenty instruments were manufactured for field trial evaluation in 1975, when the objects were twofold.

(a) To assess the potential accuracy of the system under practical conditions.

(b) To formulate, as accurately as possible, the moisture contour charts for hay and grasses.

The assistance of a considerable numbrr of agricultural institutes and commercial research establishments was enlisted.

Measurements continued throughout 1975 and totally more than 3000 results were taken on as many different samples. Oven drying measurements were made on each. The largest group of measurements was made at NIAB Cambridge on the following materials:

Perennial Rye Grass, Italian Rye Grass, Cockfoot, Timothy, Lucerne Grass, Red Clover, White Clover, Whole Crop Maize, RvP.

Special note was made of such factors as:
First or second crop.
How cut (ie long or short).
Time before or since flowering.
Strain of crop.

A master chart of X against Y (or $\log_{10}$ G against $\log_{10}$ C) was compiled of all the measurements made during the season. On this chart, moisture contours were plotted by "eye" and these were subsequently compared with the results of a computer analysis of the results (qv).

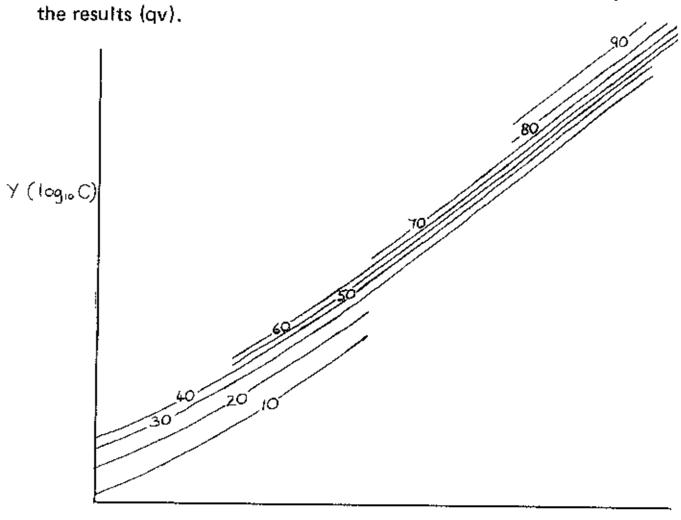


Fig 6 Plot of X against Y and resulting moisture contours

Observations

By comparing each individual result with the indicated moisture as taken from the comprehensive chart the accuracy of measurement was estimated.

The results were graded good, fair and bad according to the following criteria:

MC 0 – 40%	less than ±2%	good
	between ±2% and ±4%	fair
	greater than ±4%	bad
MC 40 – 60%	less than ±3%	good
	between ±3% and ±6%	fair
	greater than ±6%	bad
MC 65%+	less than ±5%	good
	between ±5% and ±8%	fair
	greater than ±8%	bad

Each individual result was an average of between 3 and 10 readings, (normally 10). As wide a range of materials and moisture contents was examined as possible, as previously mentioned.

The results were as follows:
Good – 203
Fair – 62
Bad – 50

→ *page 20*

Of the bad results 43 were taken on three instruments which were subsequently found to be prone to drift. The causes of the drift, which was confined to the electronics, were diagnosed as being:

(a) changes due to variation of battery voltage.

(b) drift in phase angle of the electronics system causing X and Y readings to move in opposite directions.

(c) drift in operation of the signal compression.

These faults have since been eradicated.

Computer analysis

The relationship of the three variables of capacitance C (Y),, conductance G (X) and moisture content (Z) was examined and a best fit third order polynominal was evolved for several moisture ranges ie 0 – 20%, 20 – 40%, 60 – 70%, 70 – 80%, and 80 – 90% using the 3000 practical results obtained in 1975.

The equation was in the form:–

$$Z = a_o + a_1X + a_2X^2 + a_3X^3 + b_1Y + b_2Y^2 + b_3Y^3$$

The coefficients derived were as follows:–

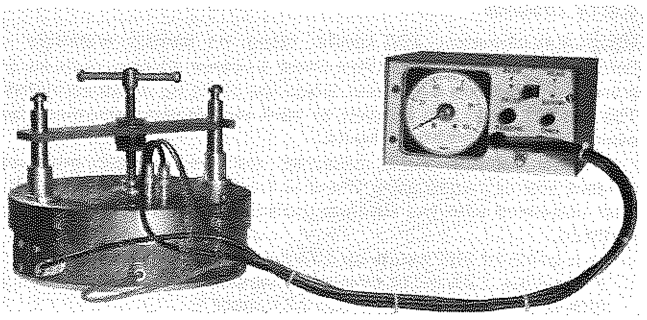


Fig 7 The final instrument

materials other than hay and grasses are to be measured, by simply removing the contour section of the rule and replacing it from a selection of other slides one can make measurements on silage, grain or any other material for which contours have been prepared. Moreover, the instrument can be repeatedly updated and its scope for more materials broadened.

Z(%)	a_o	a_1	a_2	a_3	b_1	b_2	b_3
0–20	–1.5376	–0.074686	–0.33092	–0.03751	0.0475	–0.00079732	4.8115×10^{-6}
20–40	–0.92205	0.32795	–0.1889	–0.02134	0.037101	–0.00064712	4.0459×10^{-6}
40–60	–0.89289	0.50636	–0.13894	–0.019772	0.028862	–0.00036895	2.0572×10^{-6}
60–70	0.15405	1.418	0.21097	0.022011	0.012729	–0.00010548	6.2101×10^{-7}
70–80	–0.47641	0.91517	0.0045868	–0.0024736	0.037759	–0.00064695	4.1341×10^{-6}
80–90	–0.95008	0.38786	–0.16887	–0.020432	0.031674	–0.00045313	2.5462×10^{-6}

The group variance in X for the graphs were:

Z(%)	Variance in X
0–20	0.012709
20–40	0.0094642
40–60	0.006221
60–70	0.0029443
70–80	0.010693
80–90	0.011905

The significance of this variance is different according to the position on the chart at which it occurs, ie where moisture contours are closest together 0.127 can represent up to 5% in Z and where they are wider spaced it represents as little as 0.5%. However, where the moisture contours are closest together, in the centre ranges 40 – 70%, the values of variance are lowest and correspond to only 2%.

The practical instrument

Since, and as a result of, the 1975 field trials the instrument has been refined in a number of ways to enhance accuracy, as previously described, and to facilitate use by the farmer.

One major advance has been the use of a device, similar in operation to a slide rule, to render the chart unnecessary.

This slide rule offers two sets of moisture contours – high range and normal range.

The "normal range" involves a square law compression of scales whilst the "high range" involves a fourth power compression. The division of scales provides a greatly enhanced resolution in the area of moisture most farmers are concerned for ie 10 – 55%, whilst allowing measurement of up to 85% using the "high range".

A great advantage in using the slide rule approach is that, when

Another feature of the practical instrument is a warning light which will indicate should there be an inbalance of either X or Y readings, possibly caused by shorting within the cell when it is "swamped" with moisture or by a high "shunt" value due to dirt in the reference cell. In either case the remedy is to dry or clean the cell. Practise has shown that such occurrences are rare but it is worth guarding against them.

Current and future work

Since early 1976, when the instrument design was completed, further empirical work and data analysis has been done. Five thousand examples have been measured compared with the oven method. The results reinforce the belief that the equipment is a practical unit.

Work is continuing on the measurement of silage samples. Investigations into the use of grain crops are also planned.

Useful bibliography

Hasted J B – *Aqueous Dielectrics,* Chapman & Hall, 1973.

Nelson S O – Dielectric properties of grain and seed in the 1 to 50 MC range, trans ASAE 1965, 8(1).

Corcoran P T, Nelson S O, Stetson L E, and **Schlaphoff C W,** – Determining dielectric properties of grain and seed in the audio-frequency range.

Parsadanyan S T – High frequency methods of determining the moisture content of soil. *Mekhan Elektrif* sots, Sel, Khoz 1972 30 (4) 52 – 54.

Rolfe V S – Measurement of the moisture content of media with a variable conductance. *Mekhan Elektrif* sots, Sel, Khoz 1972 30 (7) 51 – 52.

Subject index of papers published in The Agricultural Engineer, 1977

PAPERS are listed under headings as used in earlier indexes. A Ten Year Index will be issued in 1982.

Mechanisation

The faults — the utilisation and performance of field crop sprayers	Rutherford I	2
Application techniques (for crop chemicals).	Basford W D	2
The contractor's view (of crop protection).	Long P J	2

Overseas Agricultural Engineering and Mechanisation

Cultivation trials with ox-drawn equipment in the Gambia 1973-75.	Matthews M D P and Pullen D W M	3

Pest and Weed Control

Developments in crop protection methods and machinery.	Byass J B and Gedye I D	2
Application needs in relation to the expanding UK and world market for crop protection in chemicals.	Elliott J D	2
Formulation and the machine.	Amsden R C and Southcombe E S E	2
The faults — the utilisation and performance of field crop sprayers.	Rutherford I	2
Application techniques (for crop chemicals).	Basford W D	2
The contractor's view (of crop protection).	Long P J	2
The future (of crop protection).	Harris D A	2

Root Crop Production, Harvesting, Handling and Storage.

A statistical review of harvesting and storage losses in cereals and pulses, sugar beet, potatoes, vining peas and beans.	Theophilus T W D	1
The minimisation of crop losses associated with sugar beet harvesting.	Davis N B	1
The design and operation of potato harvesters for minimum damage and losses.	McRae D	1
Recent developments in potato storage.	Burton W G	1

Soil and Water Engineering

Field drainage and field work days: Results from a national experiment.	Armstrong A C	4

Tractors

Ground drive equipment and aids to extend trafficability limits and minimise soil structural damage.	Gee-Clough D	4

Institution Matters

A new approach to conference convention.	Curson U G and Neville J H	1

BOOKS

Water retention, porosity and density of field soils

Technical Monograph No 9, Soil Survey of England and Wales, Rothamstead Experimental Station, Harpenden, Hertfordshire, price £1.00.

THIS monograph details the results of measurements made on water retention, porosity and density for a wide range of top and subsoils in England.

The laboratory and field techniques are described with details of the statistical techniques used to explain the variances.

Water retention values have been added to soil profile diagrams; they have been shown to be of value in interpreting and classifying the profile.

The final chapter attempts to relate the practical significance of the earlier work by discussing the agronomic aspects of the findings. The effect of land use upon these properties is discussed, based upon an air capacity and available water classification.

The monograph is a well written document, worthy of the attention of all those with interests in the physical conditions of the soil. It introduces potentially useful concepts and contains valuable data.

RJG

The science of life

The science of life (contributions of biology to human welfare) edited by K D Fisher and A U Nixon. Plenum Publishing Corporation, 1977, price $7.50.

THE monograph reviews the results of research in the biological sciences and the bearing which these works have upon our daily lives, our health, food, environment and the utilisation of natural resources. The implications in basic bio-medicine, clinical and dental medicine are discussed and there are chapters devoted particularly to population biology, to environmental hazards induced by man and to the interaction between man and the natural resources available to him. It should be remembered, however, that this American book deals almost exclusively with biological sciences in the USA. The material is convincingly presented by respected authorities in their individual fields. There is the obvious conclusion that modern biologists must rely heavily on other disciplines in a team approach to problem solving. Pollution reduction, disease control and attempts to solve the world's nutritional problems, based on biological research, are dealt with very clearly. The book is likely to be of general interest to the agricultural engineer, to be borrowed from the library rather than purchase for himself.

HDT/BCS

The foundry directory and register of forges

BUYERS of castings or designers using castings will wish to know of this completely revised directory, which the publishers say has a currency of two years.

The four sections of the book are as follows:—

Part 1 Provides the names of all the UK ironfounders, together with their capacities and types of casting undertaken.

Part 2 Provides information on manufacturers of steel and non-ferrous castings. Also shown is the material used and the types of casting undertaken (eg Jobbing, Repetition).

Part 3 Similar information as in Part 2 but dealing with forges.

Part 4 Data on manufacturers of foundry equipment.

Published by The Standard Catalogue Co Ltd. £7.

Green crop fractionation —

Proceedings of Occasional Symposium No 9 organised by the British Grassland Society and the British Society of Animal Production.

GREEN crop fractionation is about separating and conserving the large amount of protein in a green crop which, with present conservation methods, is either lost or is only available to ruminants. If green crop fractionation became a commercial reality it would offer a weather independent method of forage conservation and also provide a source of vegetable protein for humans and monograstric animals.

Many people however, are disappointed with the progress to make green crop fractionation an economic feasibility and are sceptical about its future. For example Colin Tudge, Forum, *New Scientist* 29 September 1977 said. "The more I think about leaf protein the more it bothers me. It belongs, with Zeppelin and the flying boat, among technology's tragic heroes: a stroke of genius destined to change the world but doomed by its own sheer inappropriateness".

The contributors to the 20 papers at the symposium do not share Tudge's view. The proceedings provide up to date information on research and commercial developments on all the important aspects of green crop fractionation. Authoritative papers are presented under the following headings:—

(i) Crop production and initial fractionation.
(ii) The utilisation of juice and the pressed forage.
(iii) The utilisation of leaf protein concentrates and isolates. (Isolates are the protein-rich fraction, containing at least 85% crude protein, precipitated from the supernatant remaining after the removal of the chlorophyll—containing protein).
(iv) The production of leaf protein and isolates.
(v) Appraisal of various systems of green crop fractionation.

What is apparent, from reading these papers, is how much research and development is being done on most aspects of green crop fractionation, the exception being in the development of appropriate equipment and processes. The only report of such work comes from the University of Wisconsin. It would seem that if green crop fractionation is to become a practical reality, the effort put into engineering research and development must at least match that put into other aspects of green crop fractionation.

Green crop fractionation can be recommended to all those who require an easily read account of current developments in this field. The tables and graphs supplementing the written text are of a high standard. The extensive references will prove useful to those who wish to consider the topics in detail.

Published by British Grassland Society. Price £5 post free.

DSB

Farm wastes handbook

ALAN ROBERTSON's handbook is written for advisers and farmers and contains an excellent summary of the constraints imposed by the characteristics of wastes and by environmental and other factors. He believes that farm wastes should be treated as a useful by-product rather than as "wastes" in the conventional sense, and that their management should be an integral part of farm planning. His objective is to show how, by good design and management, it is possible to reduce or eliminate many handling, storage and air or water pollution problems.

The types of waste handling systems and equipment currently available are clearly reviewed and illustrated, the design of slurry storage and handling facilities within and near livestock buildings being covered particularly well.

The results of research into slurry separation, biological treatment, and methods of recycling wastes to livestock or to land are briefly reviewed. However, the pace of development in these fields is rapid, and information that was up to date at the time the handbook went to press inevitably will need to be modified in the light of recent experimental or practical results. For example, new equipment for slurry separation, and new data on the application of slurry to land and on treatment for odour control, have recently become available.

The handbook must prove most useful to advisers, farmers and others who are planning new waste managements systems or modification to existing ones, and Mr Robertson and his publishers are to be congratulated for presenting so much information and data in such a readable, well-illustrated and attractively produced form. It is well indexed and includes a number of useful references to other publications at the end of each chapter. The appendices include lists of the manufacturers of slurry handling and storage equipment, but inevitably these have already become slightly outdated and incomplete.

Published by Scottish Farm Buildings Investigation Unit, £2.50.

RQH

Oil-immersed brakes and clutches

THIS book contains the papers presented at the IMechE Conference on 'Oil-immersed brakes and clutches' held at the Institution headquarters in March 1977.

Eleven papers are presented covering recent work into the theoretical, practical and testing aspects of lubricated friction pairs.

→ *foot page 24*

Desert creep — A challenge to the agricultural engineer

G de Z Rajakaruna

ON 29 August 1977, representatives of a hundred nations met in Nairobi, Kenya to discuss a problem faced by many tropical countries today — that of desertification or "desert creep". The conference revealed that one third of the world's total land area is desert or semi-desert. This is the home of one in seven of all persons in the world, one in three of all sheep, one half of the world's cows and two thirds of all goats. The fear is growing that this is too much for the fragile desert ecology to support, and it is even thought that by demanding too much and by changing its resources, man is unwittingly making the desert grow. This is the phenomenon termed "desert creep". The conference was concerned that if nothing is done, this creep could become a gallop, and took as its main theme the consideration of what action could be taken to slow, and eventually reverse this trend. Coming on the heels of the successful water conference in Argentina in March 1977, it was also hoped that the Desertification Conference could put politics aside and concentrate on straight talking about a common problem.

The tragedy of the African Sahel was fresh in the minds of all the delegates at the Nairobi Conference, whilst the two year drought in the south west of the United States of America showed how urgent the problem has become. UN experts consider that more than four fifths of ecological problems in the desert are caused by man.

In good years it is all too tempting to push farm plots deeper in to the sands; to bring more sheep and goats in to nibble the sparse grasses; to erect an impressive and costly network of pipes, beneath the sand, pumping in water from miles away, or drilling deep in to the earth to "mine" the water trapped far below the surface. But farms and livestock denude the desert of its natural cover and when the rains stop nothing is left to hold the sand at bay, and unlike the surface rivers and streams that are part of a constant cycle of rain and evaporation, deep ground water is replaced by nature only over long periods.

In a plan of action presented to the Nairobi talks, the governing council of the UN Environment Programme suggested several ideas for consideration. Some were as follows:

a. Adoption of both economically and ecologically sound new land reclamation practices;
b. inclusion of schemes such as water rights, credit and insurances in whatever land-use plan is adopted for each area;
c. consideration given to evacuation of the people out of those areas where desirable.

These suggestions raise a certain number of questions. If people are to be moved out of an area, where can they go? How can they find other work? How can the already swollen cities feed and house them? Such questions do not have easy answers.

Water of course, is more precious than gold in the deserts. The plan suggested everything from building small earth reservoirs to controlling the installation of wells and pumps. Further it suggested more thought should be given to — letting desert land lie fallow in alternate years; planting cover crops to hold the soil; developing new fertilisers for desert environment; levelling sand dunes. Terracing and contour planting also help prevent erosion as would minimum tillage farming.

The plan also urged that livestock should be removed from drought areas to let the land recover. Herds must be kept to optimum size, and grazing areas rotated just as crop areas. The necessity for new irrigation ideas was another of the major points discussed in the conference. One big problem in the desert is, ironically, too much water. Lowlands may actually get waterlogged. Fully one quarter of all irrigated land suffers from this problem, or the companion problem of salinity.

How does one stabilise the moving sands, especially around the desert margins or in areas trampled by tourists or left denuded by strip mining or wood gathering? So called "green belts" of trees was one idea put forward at the talks. Stable surfaces on roads and fencing dunes to keep people or animals out and let the natural grasses take hold again, were the other proposals made.

US officials, while happy with the detailed proposals being made, felt nevertheless that the plan of action was too broad and too ambitious. But as the home of one of the most extensive deserts on earth, the US was enthusiastic about the conference. As its contribution to the conference, the US produced three films on its experience in desert problems and their management.

The United Nations have prepared several case studies of deserts and how man has contributed to their spread. Chile and Tunisia were chosen as examples of deserts which receive most of the rain in winter. India and Niger were cited as examples of summer rainfall. In addition several nations have submitted studies of their native deserts. These include USSR, US, Australia, China, Iran, Israel. Another panel of experts is working on feasibility studies of desert problems that can be attacked by international action. One includes reviving grazing lands in Chad, Mali, Mauritainia, Niger, Sudan and Upper Volta. A second involves ground water supplies in Chad, Egypt, Libya, Sudan and Arabian Peninsula. A third study focuses on problems in Afghanistan, India, Iran and Pakistan.

Two studies contemplate dramatic "green belts" — walls of trees stretching across both the Sahara and the Sahel as barriers against invading sand.

Summing up, "Desert Creep" has thrown an open challenge to the agricultural engineer.

Books cont

Automatic transmissions, industrial powershift transmissions, synchromesh mechanisms and solid lubrication in aircraft brakes are among the diverse applications discussed. Two papers are devoted entirely to test rigs for wet brakes and clutches and four, including one theoretical analysis, deal generally with factors influencing the performance of lubricated friction pairs (in particular, the lubricating fluid). Grooving of friction materials is obviously a subject of particular interest and appears in several papers, though the mechanism by which it operates is not fully understood.

The general presentation is rather austere; there is no additional summary or discussion to link the papers, which are not arranged under subject headings. The individual presentation of the papers varies with the author but in particular the first paper is an excellent summary of the performance of lubricated friction pairs by workers from Shell Research Ltd. Overall, this book is useful as a reference for transmission engineers who want to keep informed of recent work in the specialised area of lubricated friction mechanisms.

Some errors and omissions in the list of contents may confuse the unwary.

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Congress of Rural Medicine

THE Seventh International Congress of Rural Medicine, organised by the International Association of Agricultural Medicine and Rural Health, will take place in Salt Lake City, Utah, United States of America, from 17–21 September 1978.

The aim of the Congress will be to focus upon the occupational and environmental health aspects of the anthropozoonoses, ergonomics, living and working conditions, medical care, mother and child health, nutrition, social hygiene and public health and toxicology.

Details may be had from: L W Knapp, Institute of Agricultural Medicine, Oakdale, Iowa 52319, United States of America.

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