The Agricultural Engineer

Incorporating **Soil** and water

Volume 46 Number 1 Spring 1991

Fans for today's agriculture

Institution of Agricultural Engineers

1991 Annual Convention

Wednesday 8th May, 1991 – University of Newcastle upon Tyne

Agricultural engineering and the environment

Plenary sessions

10.30 **Introduction**
Chairman of the Conference: P Johnstone – Engineering Consultant (former Regional Engineering Manager NRA).

10.35 **Economic factors influencing the agricultural environment**
Professor D R Harvey – University of Newcastle upon Tyne.

11.15 **Physical factors influencing environmental change**
Professor M D Newsome – University of Newcastle upon Tyne.

11.55 **Engineering opportunities in the environment**
Professor J R O'Callaghan – University of Newcastle upon Tyne.

12.35 **Discussion**

12.50 **Closing remarks by the Chairman**

....

Parallel Specialist Group Sessions

14.00-1440

Vehicle — **Measurement of combined lateral and longitudinal forces on tyres**
Dr D A Crolla – University of Leeds

Soil and Water — **The role of soil erosion in NPK movement from the soil**
Miss J Rickson, J N Quinton – Silsoe College

Electronics — **Redesigning field instrumentation**
A Philips – Delta-T Devices Ltd.

1440-1520

Forestry Engineering — **Timber haulage transport**
M Doxley – Forestry Commission

Crop drying and storage — **Drying grain quality: thermal processing of dormant malting barley**
Dr J L Woods, J Favier – University of Newcastle upon Tyne

(Overseas) — **The role of the agricultural engineer in overseas development.**
(Followed by: **Do we need a Specialist Group?**)
D H Sutton – AFRC Engineering, Silsoe

1520-1600

Machinery management — **Financing agricultural machinery**
M Tipper – Farm Business Consultant

Technical demonstrations

Decision support system for land use planning
R Wadsworth – University of Newcastle upon Tyne

Work in the crop processing and electronics laboratories
Dr J L Woods, T T McCarthy – University of Newcastle upon Tyne

1830 for 1900

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Principal guest: A Grant, Chairman, AFRC.

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Incorporating Soil and water

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Journal and Proceedings

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Fans for today's agriculture

In this paper which was presented to the Institution's Specialist Group on Crop Drying and Storage, W T W Cory takes us through how fans work and briefly describes what types of fans are available. He then deals in depth with axial fan classification, construction and theory.

In later issues centrifugal and mixed flow fans will be covered in detail together with the problem subject of noise.

It is many years (ie 1953!) since W G Cover and R C Dick presented their paper to the then Institution of British Agricultural Engineers on "Fans in Agriculture". Although the fan industry may be considered a mature one, developments have nevertheless taken place, and a review at this time is appropriate.

In the intervening period, energy costs have risen substantially, such that the demand for higher efficiency units has become widespread. Furthermore, the change in methods of crop drying has in itself forced us to review our selection of fan types and their applicability to the flowrate and pressure specifications now required.

In January 1990, new Health and Safety Executive (HSE) regulations concerning noise in the work place came into force. These are but the prelude to an EEC directive, even more strict in its requirements, which will be enforced from about 1994.

The intention of this paper is, therefore, to highlight some of the theoretical considerations in the design of fans both as to aerodynamic performance and to noise generation.

What is a fan?

Fans are built in all shapes and sizes. They run from the very lowest to high speeds. Their performances are just as different. Whilst it may be obvious, let us therefore, have a general definition. Hopefully, we can agree on this at least. That which follows is my own. It is coloured, of course, by the texts which I have read, and my experiences over the years:

"A fan is a rotary bladed machine which delivers a continuous flow of air or gas at some pressure, without materially changing its density".

The words have been carefully chosen. Our sort of fan is not something for old fashioned ladies to hide behind – thus the requirement for rotary motion. The flow is continuous into, through and out of the unit. This distinguishes it from positive displacement machines with pistons, vanes or lobes where the flow pulsates. A maximum pressure rise or density change has to be included to differentiate between fans and compressors.

A boundary exists somewhere, and in the United Kingdom we now define a fan as having an absolute pressure rise of not more than 30%. This equals about 30 kPa or 120 in.w.g. when handling standard air (ie air at 16°C temperature 100 kPa barometric pressure and 65% relative humidity).

A fan has an impeller carrying blades of some kind. These blades exert force on the air or gas, thereby maintaining the flow and raising the pressure.

There are, of course, circulating fans which do not have casings. The pressure generated is not then usable or measurable. It is devoted to produce a jet of air which in turn entrains secondary air from its surroundings.

The Fan Characteristic

We cannot easily describe the performance of a fan by a single value of pressure rise or flowrate. Both quantities are variables, and have a fixed relationship with each other. This is best plotted graphically as a "Fan Characteristic Curve". The performance also varies with speed, so that the curve is either plotted at a constant or inherent value. We generally plot the flowrate along the base, with the pressure (and other performance quantities) as vertical ordinates. A typical example is given in Fig 1.

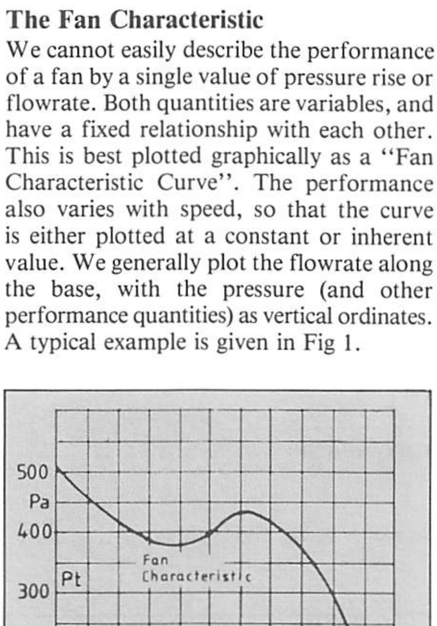


Fig 1. Pressure/flowrate curve.

There is one point on this characteristic where the efficiency is a maximum. The power consumption *for a given duty* and a particular product line is then a minimum. This usually results in a low noise value.

A fan can, however, be successfully operated at other points along the curve. This region of satisfactory operation could be defined by a heavier line. Outside this range the performance may not be guaranteed. It is likely to be unacceptable due to low efficiency, high noise or even a high price. Some parts of the curve may even lead to motor overloading, inadequate cooling (with direct drive axials), unstable operation and/or excessive vibration.

System-characteristics and operating point

To pass air or gas through a system requires pressure. The greater the capacity, the more the pressure. If we plot this pressure against flowrate, we will obtain a system-characteristic. At the intersection of the system line and the fan curve, they will be in balance. This is the fan operating point.

Generally, with fully turbulent flow, and with fixed elements of the system (eg ducting), the pressure required will vary as the square of the flowrate, ie $p_D \propto Q^2$. For the grain bed or other crop, this, of course, is not the case. Because of compaction, near laminar flow, opening of the interstices between grains etc, etc, the pressure through the crop bed will vary as some power n of the flowrate, where n is a figure less than two, ie $p_B \propto Q^n$. In most crop drying systems, both elements of system pressure exist and the overall system pressure

$$p = p_D + p_B = k_1Q^2 + k_2Q^n.$$

It should be noted that, as the fan and system curves have to be in balance, there is a strong stabilising effect on performance. This is especially the case where the fan curve falls steeply with increasing flow (see Fig 2).

Fan pressure

Complete characteristics of this same fan are shown in Fig 3. The pressure has been

Bill Cory is Technical Director at Woods of Colchester Ltd, a GEC Company.

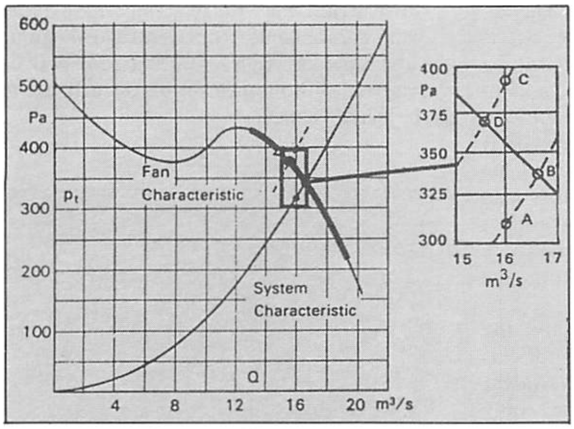


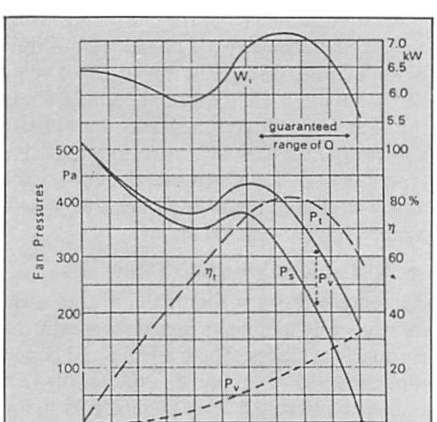
Fig 2. Fan and system characteristics.

divided into constituent parts. Fan velocity pressure is based on the average velocity at the outlet, and is a convention for the kinetic energy, whilst the fan static pressure represents the work done in compression.

Probably more heat has been generated on these definitions than on any others.

It should be noted that the static pressure is fully available to the system designer, but some of the velocity pressure will inevitably be lost. At an open fan outlet, or in a system where the cross sectional area is maintained constant, and equal to the fan outlet area, the loss is 100%. If the duct area is gradually increased or an outlet diffuser fitted, the loss can be limited to as little as, say, 25%. Most practical systems are somewhere between.

(*NB – a)* In many fans, the *actual* outlet velocity pressure is both variable and/or higher than the nominal average (see the following section – Installation categories)



1250mm axial fan – free inlet, ducted outlet, 12 rev/s, 1.20 kg/m³

Fig 3. Complete fan characteristics.

and *b)* With 'on-floor' drying systems, there is often a great disparity between the fan outlet area and the main duct cross-section, such that a pressure loss takes place. Perhaps here there is also a need for diffusers).

Installation categories

From the above, it will be appreciated that the ways in which a fan may be incorporated into a ducting system are infinite. It would be impossible to test all the eventualities. We can, however, set some sensible limits which are representative of many installations. The fan can be attached to an infinite sized duct which will not constrain it in any way, or it can be connected to a duct of the same area as its inlet or outlet. (One would not normally expect anything smaller to be used – although one does come across orifice plates fitted onto fan inlets!)

In the new draft ISO testing standard DP5801 (and also in BS848: Part 1: 1980 on which it is based) four operating categories have been recognised as shown in Fig 4:

Type A – free inlet and outlet
Type B – free inlet, ducted outlet
Type C – ducted inlet, free outlet
Type D – ducted inlet and outlet

Although it is not evident from many catalogues, it is important to know that a fan will have a different performance curve for each of these installation types. The attachments to the fan inlet and/or outlet act as an aerodynamic impedance, modifying the flow to or from the impeller. The size of these differences cannot be determined without testing. They are a function of a particular fan design.

Generally, the characteristic curves for Category A (where a pressure difference may be supported across a partition in which the fan is mounted) and Category C are small. They may usually be reduced to a minimum in the working range of the unit, by fitting a low loss entry cone or bellmouth to the Category A fan. In like manner, the differences between installation types B and D are usually small and again a bellmouth at inlet will bring the Category B up to Category D standards.

The differences between A/C on the one hand and B/D on the other, can however be substantial, for both axial and centrifugal units (Figs 5 to 7).

In an axial fan the flow is concentrated in an annulus formed between the impeller hub/motor and the casing. There is thus a considerable deceleration of the air when it leaves the fan, and a reduction in the local velocity pressure. An outlet duct enables a regain in static to be made.

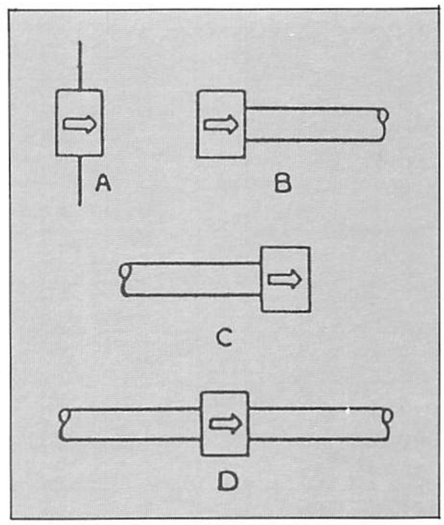


Fig 4. Standard fan installation types.

In like manner, a centrifugal fan outlet normally contains a 'shield', 'tongue' or 'throat piece'. The local velocity is therefore much higher than the average in an outlet duct. Again, velocity pressure is converted into useful static pressure.

It must be emphasised that satisfactory measurements of pressure cannot be taken immediately adjacent to the fan and it is necessary to establish test stations some distance away, where the flow can be

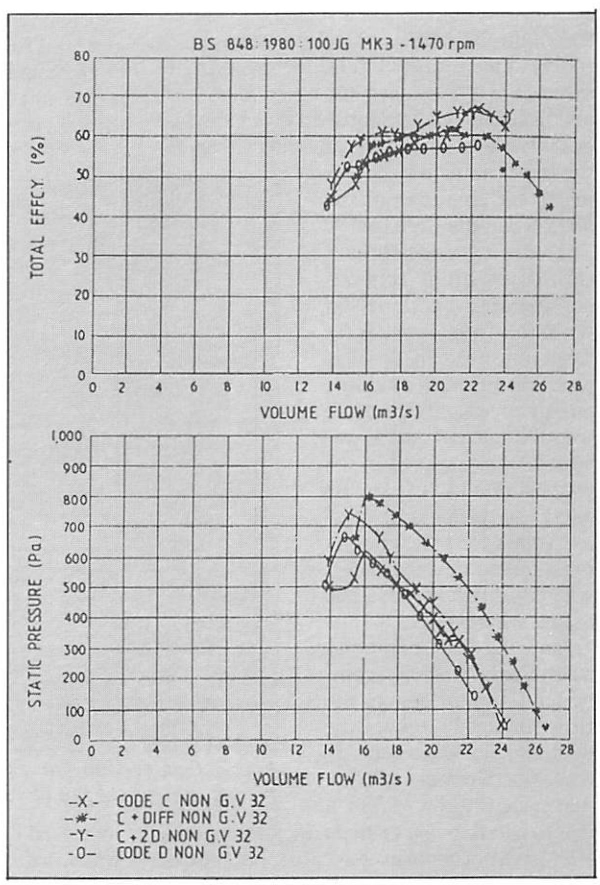


Fig 5. Effect of outlet connections on high pitch angle performance.

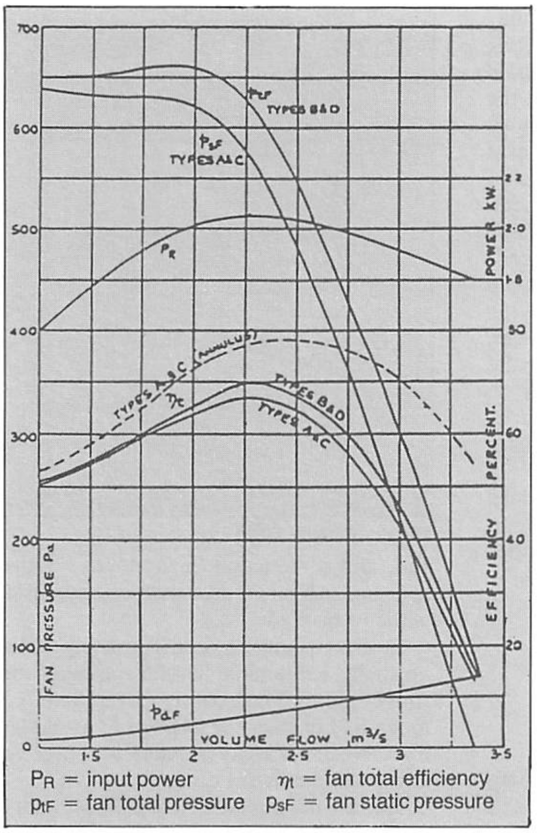


Fig 6. Performance of a mixed flow fan in installations of type A, B, C, D.

normalised. The quantity measured at these stations is the static pressure, to which is added some conventional velocity pressure, to obtain the effective total pressure.

The dimensions of this ducting on the outlet side of the fan, must be standardised and incorporate a standardised flow straightener. Without standards, differing values of pressure can result according to the character of the airflow at the fan outlet. The velocity distribution at this point often contains considerable swirl. Even when free from swirl it is far from uniform (Fig 8). This results in an excess of kinetic energy or velocity pressure over the conventional allowance of $\frac{1}{2}\rho v^2$, caused by the proportionality of kinetic energy to the local value of ρv^3 (mass flow × velocity pressure) so that the excess where v is high exceeds the deficit where v is low.

Now the non-uniformity of the **axial** velocity components diminishes as the flow proceeds down the duct and the excess energy reaches a minimum of a few percent of $\frac{1}{2}\rho v^2$ within a length equal to two or three duct diameters. Part of the original excess is lost, but part is converted into additional static pressure, the conventional velocity pressure remaining constant. This addition to the fan static pressure and the conventional fan total pressure is available for overcoming external resistance, and in order to credit it to the fan, as it should be for type B and type D installations, the test station for outlet side pressure measurement should be more than three duct diameters from the outlet.

On the other hand the **swirl** energy at fan outlet is never recovered in a straight uniform duct, and only decays over very long distances – more than 100 diameters. In the presence of swirl simple measurements of effective pressure or volume flow are impossible, and it must, therefore, be removed when tests are to be taken in a duct on the outlet side of the fan, to give information on type B or D performance. An effective flow straightener will do this, and if it removed just the swirl energy and no more, the minimum energy convention would be satisfied. However, the energy actually removed is very dependent on the combination of swirl pattern and straightener design, hence the need for an agreed standard outlet duct.

In practice a fan with a lot of outlet swirl ought not to be selected for use with *long* straight outlet side duct, because the friction loss in the latter will be substantially increased. Guide vanes should be fitted which will remove and recover (instead of removing and destroying) the swirl energy. The flow straightener will then just ensure that test conditions are satisfactory in the downstream duct: the relatively small outlet swirl components from centrifugal, guide vane axial or contra-rotating fans will be removed without measurable disturbance to the performance.

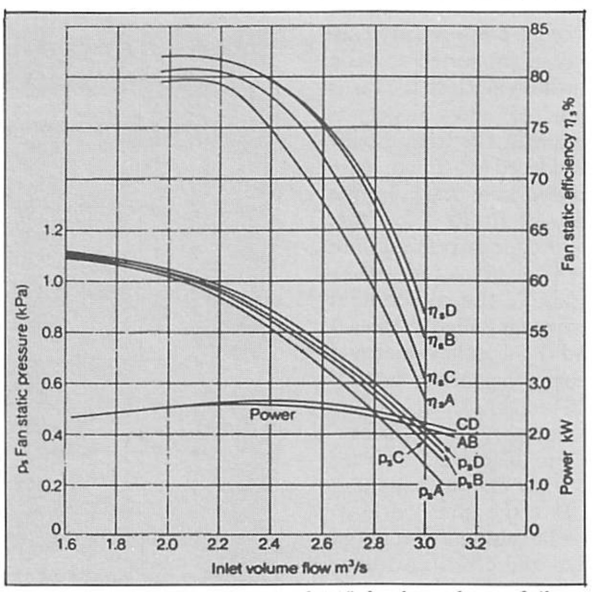


Fig 7. Comparison curves of 25" backward aerofoil bladed centrifugal fan at 1500 rpm.

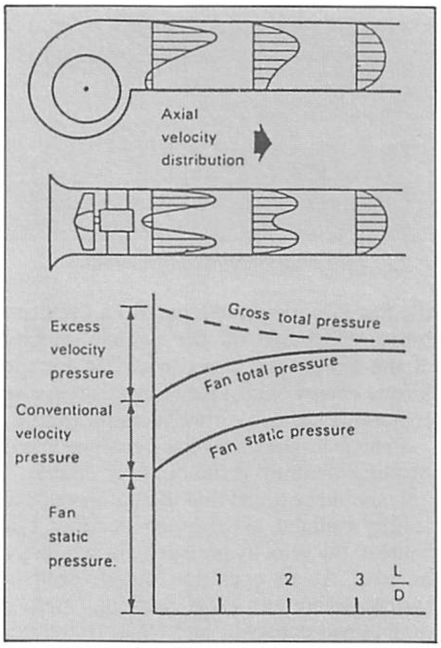


Fig 8. Velocity diffusion downstream of a fan.

Fan types

There are an infinite number of fan types possible (Fig 9), but these may be categorized into three main types (Fig 10), as follows:

- **Axial flow**

Air progresses through the impeller at a constant distance from the shaft and casing axis. The pressure rise is produced by direct blade action. As a reaction to the driving torque, there is an additional component in the tangential direction. Thus the air also spins about the axis and the resultant motion from the impeller is a spiral. Generally used where large volumetric flowrates are required against low system pressures.

- **Radial (or Centrifugal) flow**

Air enters the impeller axially and turns through a right angle to progress radially out through the blades. The blade force is largely tangential so that the air spins with the blades. Centrifugal force resulting from this spin is now in line with the radial progress of the air and results in a pressure rise. Blade action may add to this according to the outward blade force component. Used for relatively low flowrates against high pressure.

- **Mixed flow**

In a true mixed flow fan, the air enters axially and is turned outwards through some angle rather less than 90°. The blading extends over the curved part of the flow path. The blade force has a component in the direction of flow, pressure being developed by both blade action and centrifugal effects.

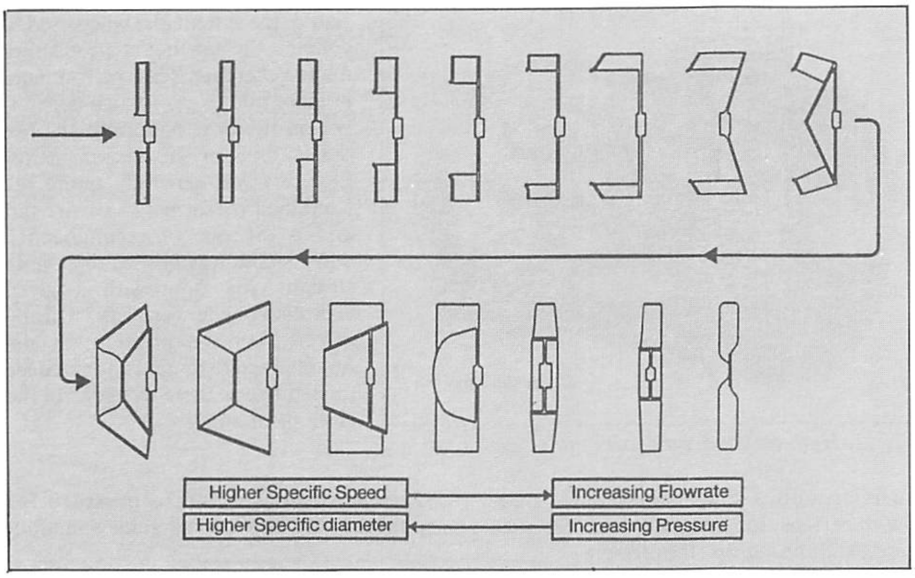


Fig 9. Fan impeller types.

predominantly parallel to the axis (but see the section on orifice flow). Normally designed to operate under free air conditions or against very small system pressure.

Axial fan construction

Impeller components: Impellers usually have blades cast in aluminium alloy with cross-sections of aerofoil shape. As compared with curved sheet blades aerofoils can apply greater force to the air, thereby increasing maximum pressure, and can maintain better efficiency over a wider range of volume flow. Also by increasing the thickness and curvature of the inner sections the blades can be made stiffer, this limits flutter and allows the impellers to be run at high speeds.

The blades of Woods' fans are invariably attached to the hubs by a system which allows the pitch angle (see Fig 14) to be set at any desired value on assembly. This

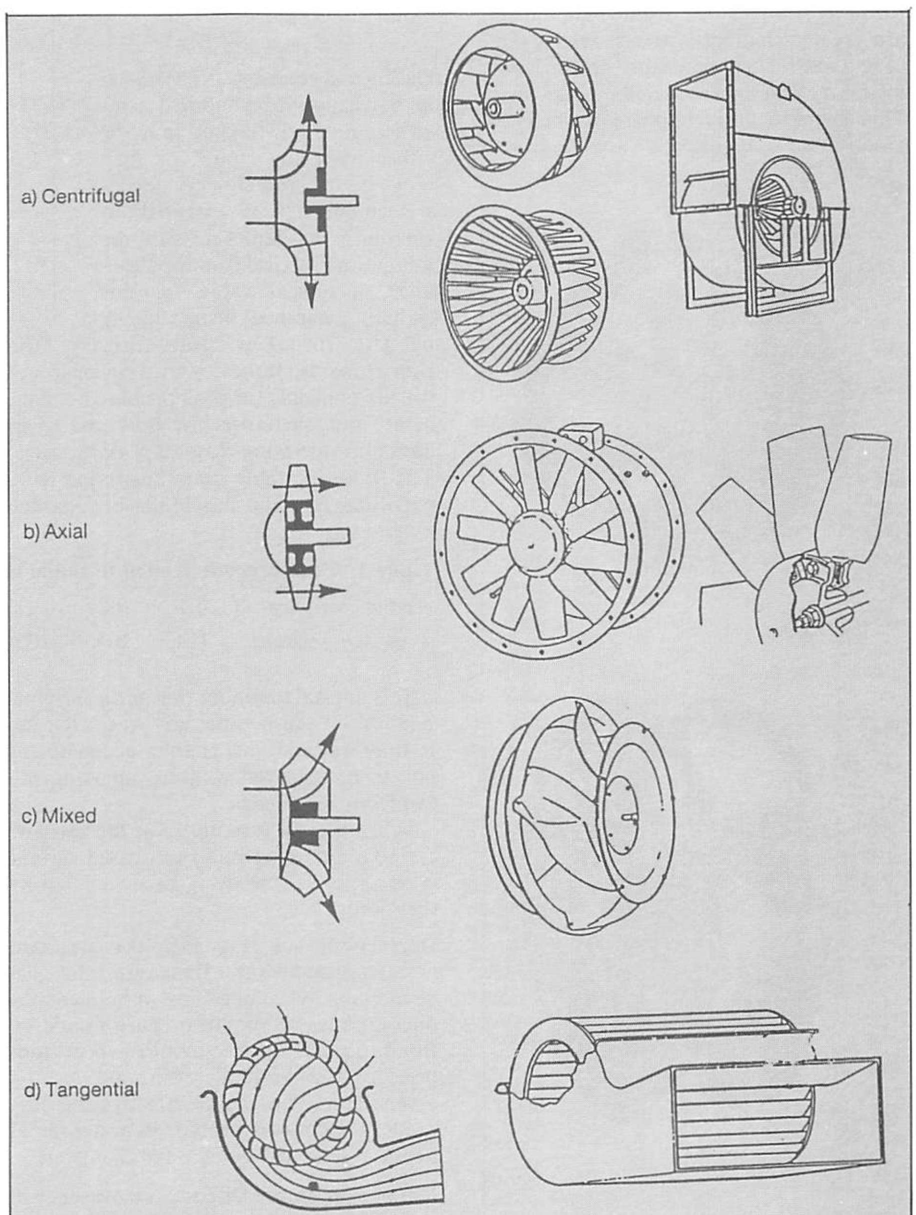


Fig 10. Generic fan types.

Intermediate in its flowrate and pressure development between axials and centrifugals.

Axial flow classification

- **Tube axials**

These are defined as axial flow fans without guide vanes. Units normally consist of an impeller mounted directly on the shaft extension of a suitable electric motor and running in a cylindrical casing. The motor, which may be of either the pad or foot mounting type, is then attached to this casing by either tie bars or a stool respectively (Fig 11).

- **Vane axials**

The definition is 'an axial fan with either inlet or discharge vanes or both'. These vanes may either be an integral part of the fan casing, or they can be a bolted-on section of duct. Their purpose is to recover swirl energy and convert into useful static pressure.

Guide vanes on the downstream side of the impeller remove the rotational velocity component, thus slowing down the air and converting some of the excess velocity pressure into useful static pressure (Fig 12).

Upstream vanes pre-rotate the air in a direction opposite to that of the impeller rotation. With careful design the air will leave the fan in an axial direction (at the specific duty point) (Fig 13).

The pressure/volume characteristics of fans with high pitch angles usually exhibit a region of discontinuity corresponding to stalling conditions at the aerofoil blades. Upstream guide vane fans tend to show a more marked stall and a narrower range of high efficiency performance. Their pressure development is, however, greater but at the expense of noise.

- **Propeller fan**

This is an air moving device with a propeller or disc wheel rotating within a mounting ring or plate through which the airflow is adjustable pitch feature enables the fan to be supplied pre-set for exactly the volume flow required, eliminating the waste of power inseparable from a range of fixed steps from which the next larger must be chosen. The combination of varying blade numbers and pitch angles enables most duties to be met at direct drive speeds.

Vanes – inbuilt or bolted on?: Fans with inbuilt vanes tend to be more compact. In the downstream version they can surround the motor. Bolted on vanes are useful from a production point of view in that the same fan can be sold with or without vanes, up or downstream. It should be recognised that spacing may be less than the optimum. From the customer's point of view, they may be added to a fan where resistance is greater than calculated, and additional pressure is required.

Why use vane axials?: Vane axials are used for systems where the pressure requirements are greater than can be achieved by the tube axials. They invariably give a higher efficiency and also reduce the outlet swirl. This is particularly important when discharging into a long high velocity duct. Swirl persists for long distances in such cases, and can increase the pressure drop several times. Structurally, vanes can be a useful means of motor support.

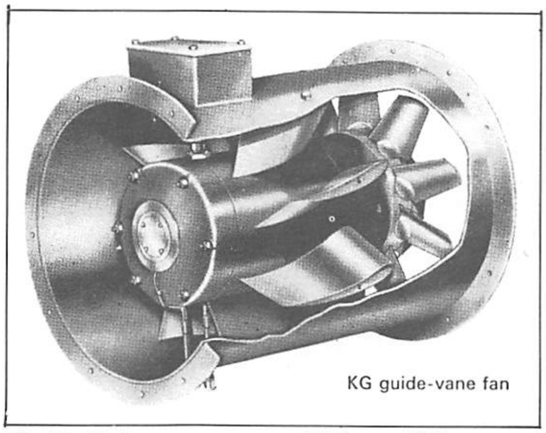


Fig 12. High pressure vane axial fan at 2950 rpm.

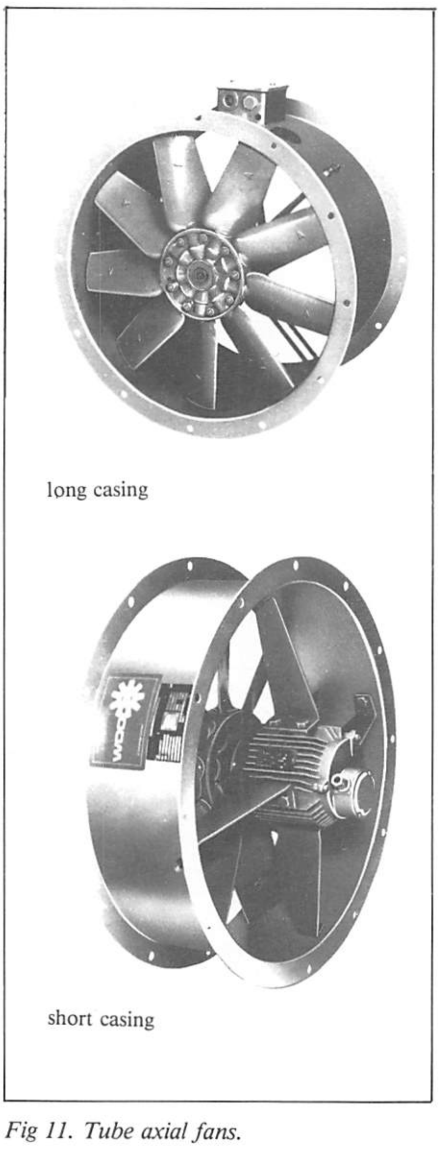


Fig 11. Tube axial fans.

Casing and accessories: The casing is normally of cylindrical construction. End flanges may be either integrally 'spun' or they may be of rolled steel angles welded on. It is essential to surround the impeller with the minimum practical running clearance, a typical value for this (radial) clearance being 0.25% of the impeller diameter. Departures from the designed tip clearance will affect mainly the peak pressure development, and, therefore, the flow rate when the fan is operating close to peak pressure. The following table is an illustration for a particular fan, and should not be regarded as general.

Table 1. Peak pressure related to radial clearance

Radial clearance	0.1	0.2	0.25	0.3	0.4	0.6	1.0	% diameter
Peak fan pressure	114	104	100	97	92	85	75	% standard

It is normal to mount the motor terminal box on the casing especially where the fan is fully ducted. This enables access to the box to be achieved without removing the fan from the ducting.

When the fan is mounted at the entry or exit to a duct system, a short cased variant is possible, as the casing need not 'cover' the motor.

Inlet conditions (Fig 15): The standard casing normally has a flange for inlet duct connection. When operating without an inlet duct an inlet bellmouth or flare should be fitted to guide the air smoothly in without breaking away from the casing and forming a vena contracta. To be effective the inlet needs a length of at least 15% and a radial depth at least 10% of the fan diameter.

Outlet conditions: Diffusers or evasees will convert some of the fan velocity pressure into fan static pressure, which is the only useful form at an open outlet. They will reduce the system loss when used to connect the fan outlet to a larger duct or chamber. Their performance in these roles is very much dependent on the flow pattern at the fan outlet, and for this reason manufacturers will generally quote the combined performance of the fan and a diffuser of recommended dimensions. It is unwise to assume straight line flow with a given efficiency. The recovery will be affected by the position on the fan characteristic and the impeller pitch angle as these will control the amount of swirl.

Contra-rotating – more pressure for nothing?: If two identical guide vane fans are run in series the fan total pressure would be approximately doubled at a given volume flow, apart from losses due to mutual interference, the fan velocity pressure remaining the same. Two non-guide-vane fans will only

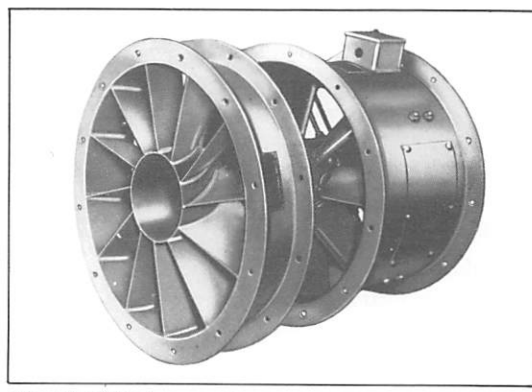


Fig 13. Bolted-on upstream vanes.

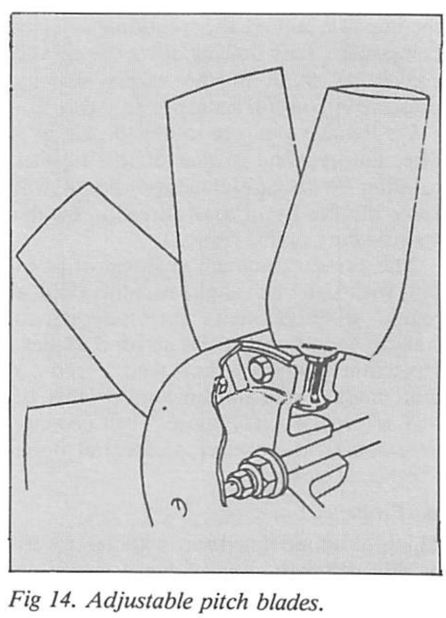


Fig 14. Adjustable pitch blades.

produce about 50% more pressure than one, since the second stage will be unloaded by the swirl produced by the first. The effect may be looked upon as a reduction in the rotational speed of the second impeller relative to the air entering it, which is spinning in the same direction.

Contra-rotating fans provide a better system of series connection. Each impeller is driven by its own motor and they rotate alternately in opposite directions. Thus each impeller cancels out the swirl of the one before and guide vanes are unnecessary. Furthermore, the second, and all even-numbered stage impellers receive air which is swirling in the opposite direction. This is equivalent to an increase in relative speed of rotation and the fan total pressure of a contra-rotating pair will be about two-and-a-half times that of a single stage.

The blades of the even-numbered and odd-numbered stages differ fundamentally from each other since one must be designed as a right-handed and the other a left-handed screw. Pitch angles are generally adjusted, so that impeller powers are equal around the best efficiency point. This automatically secures an output flow free from swirl.

Performance curves: Axial flow fans are well established for grain and crop drying applications. Manufacturers offer standard ranges of general purpose fans commonly from 300mm to 2m diameter and displacing $0.5m^3/_s$ to $50m^3/_s$ at pressures up to 750 Pa. Standard units can be operated in parallel or series to extend the range of volume flow or pressure almost indefinitely. An envelope curve is shown in Fig 16.

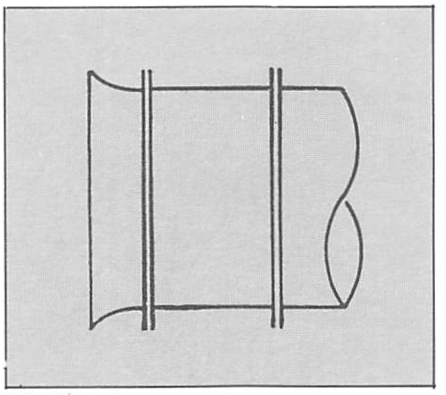


Fig 15. Inlet bellmouth.

Axial fan theory

– Pressure generation

An isometric view of the path of the air through an axial fan is shown in Fig 17. A small portion of the total flow is considered, confined between two imaginary cylinders of slightly differing diameter. Radial forces are assumed to be so balanced that the air which enters flows wholly between the two cylinders with no tendency to escape, outwardly or inwardly.

As the air passes through the rotating impeller, forces exerted by the blades give it a spinning motion so that it leaves the impeller in helical paths as if guided by a very long-pitch screw thread.

The condition of radial balance enables the imaginary cylinder to be unrolled flat so that helical paths become straight lines, easier to handle mathematically.

Velocities are represented by vectors giving the magnitude and direction of the air flow. These are distinguished as follows:

- v_1v_2 – actual or absolute air velocities.
- u_1u_2 – peripheral velocity of blade at radius considered.
- w_1w_2 – air velocities relative to the rotating impeller.
- 1,2 – suffixes indicating inlet and outlet sides of impeller.

In the absence of external forces air will enter the fan in the axial direction v_1. To find its velocity w_1 relative to the leading edge of the moving blade, we must subtract the blade velocity vector u_1 (that is add $-u_1$) to the air velocity vector v_1. This operation is performed by drawing the vector triangle as shown. The impeller will be so designed that, at the 'design point' volume flow and corresponding inlet velocity w_1 will meet the blade at the most favourable angle of approach.

The blade is given an aerofoil shape designed to deflect the relative velocity in the direction of rotation from w_1 to w_2. Note that the components w_1 and w_2 in the axial direction must be the same since there is the same volume flow in the same annulus area at inlet and outlet. It follows from the geometry of the flow (note also the increase in blade passage width from s_1 to s_2 that w_2 must be less than w_1. The corresponding fall in the relative velocity pressure, ($\frac{1}{2}\rho w_1^2 - \frac{1}{2}\rho w_2^2$) results in an unequal rise in static pressure ($p_{s2}-p_{s1}$) within the impeller from blade inlet to blade outlet.

Now, static pressure is an absolute property of the air which does not change with the frame of reference. Therefore the rise of static pressure within the impeller is

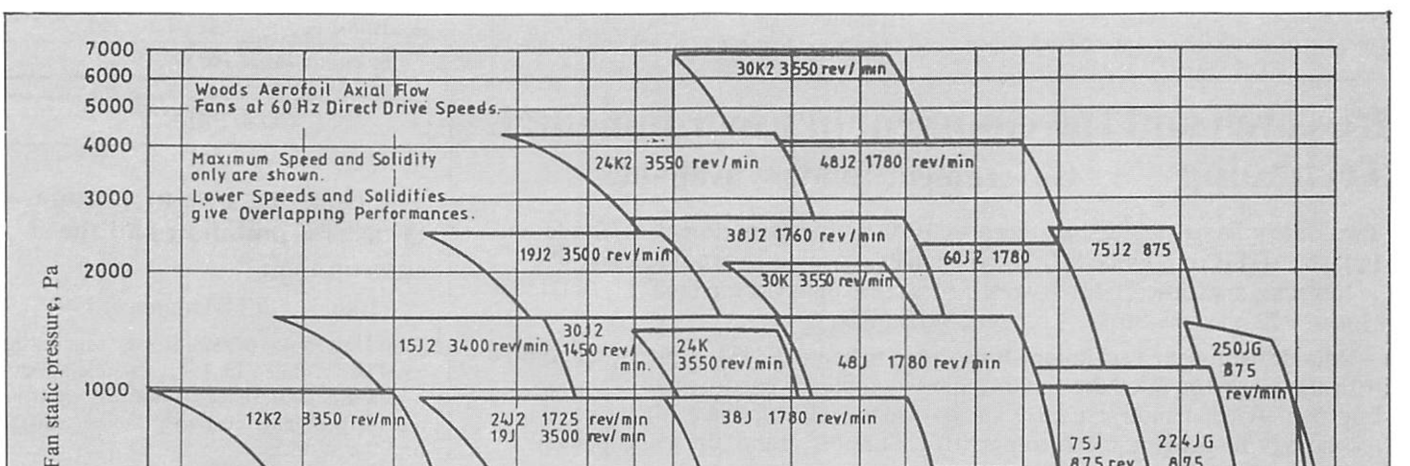


Fig 16. Performance coverage chart.

also the rise of static pressure external to the impeller from the inlet to outlet side. A fall in relative kinetic energy has been transformed into a rise in absolute static energy. The vector diagram on the outlet side, u_2, being the same as u_1, shows that the absolute velocity v_2 is increased as well as deflected from v_1. With a little rearrangement the two diagrams can be combined into the composite vector diagram which shows the velocity changes quite clearly. We can now determine the total pressure rise across the impeller (p_{t2}-p_{t1}). Since

$$p_{s2} - p_{s1} = \tfrac{1}{2}\rho(w_1^2 - w_2^2)$$

$$P_1 = p_{t2} - p_{t1} = (p_{s2} + \tfrac{1}{2}\rho v_2^2) - (p_{s1} + \tfrac{1}{2}\rho v_1^2)$$
$$= \tfrac{1}{2}\rho(w_1^2 - w_2^2 + v_2^2 - v_1^2) \quad (1)$$

An alternative expression can be found with the aid of the absolute flow angles as shown, together with the relative flow angles ß. For our particular case $a_1 = 90°$ and $u_2 = u_1$ while there is no change in the axial component of v, ie $v_2 \sin a_2 = v_1$.

$w_1^2 = v_1^2 + u_1^2$

$w_2^2 = v_1^2 + (u_2 - v_2 \cos a_2)^2$

Therefore $w_1^2 - w_2^2 = 2u_2 v_2 \cos a_2 - v_2^2 \cos^2 a_2$

$v_2^2 - v_1^2 = v_2^2 - v_2^2 \sin^2 a_2$

Substituting in (1) and remembering that $\sin^2 a_2 + \cos^2 a_2 = 1$.

$$p_t = \rho u_2 v_2 \cos a_2 \quad (2a)$$

In the general case, where $\alpha \neq 90°$ and $u_1 \neq v_2$ we can show that

$$p_t = \rho(u_2 v_2 \cos \alpha_2 - u_1 v_1 \cos \alpha_1) \quad (2b)$$

– Deviations from the theory

This idealised treatment is only a starting point. Further factors the designer must consider include the following:

- The air will not leave the impeller at the angle set by the trailing edge of the blade. There will be a deviation angle tending to reduce input and output power. This is a function of aerofoil shape and blade loading.

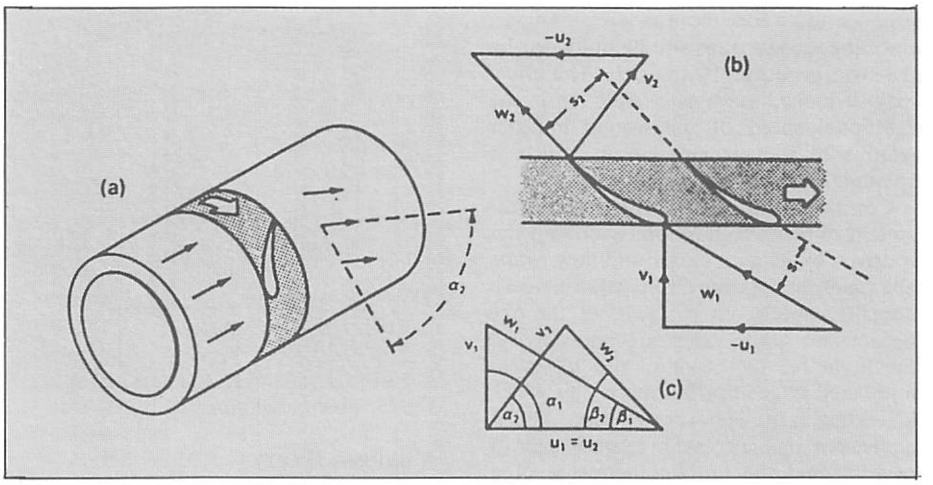


Fig 17. Axial flow mechanisms.

- The air will meet the leading edge of the blade at the optimum angle only at the design volume flow. At other flows the incidence angle will change. The effect of this change on performance over the whole fan characteristic is again a function of aerofoil shape and loading.
- To keep the portion of flow considered between the imaginary surfaces defining its intended path requires a balancing transverse pressure gradient. In an axial flow fan only the so-called free vortex pressure and velocity distribution will secure flow at constant radius along concentric cylinders. This distribution requires a constant value of rv cos a, ie a spin component which is smaller the bigger the radius. This limits the work done towards the blade tips, giving a fan of poor power-size ratio; to overcome this weakness forced vortex designs are usual, increasing tip work. To maintain balance the streamlines tilt outwards through the impeller, so that r_2 and u_2 are greater than r_1 and u_1 making it necessary to use equation (2b) rather than (2a).
- Viscous drag forces at the blade surface and wake effects behind the blade convert some of the work input into heat instead of useful pressure rise.
- Tip clearance effects and boundary layer retarded flow along casing, hub, backplate and shroud spoil the flow pattern at the ends of the blade and limit the work done (input and output).
- The velocity leaving the blades is usually far from uniform in magnitude or direction. Since the energy is proportional to the square of the velocity, more is required by the peak velocities than is saved in the troughs. Thus excess kinetic energy is supplied which will not all be available when the air has reached the downstream test plane.

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To be continued in the next issue

Research and Development in Environmental Technology – Government funding available

Two new schemes were announced in 1990 by the Department of Trade and Industry (DTI) to provide help to companies pursuing environmental R&D.

Introductory leaflets on the two schemes are available from the DTI, Ashdown House, 123 Victoria Street, London SW1E 6RB.

– The Environment Technology Innovation Scheme (ETIS) – promoted jointly with the Department of the Environment – aims to encourage innovation, to improve environmental standards and to help users or suppliers of environmental technology to become more competitive. Support grants up to 50 percent of project costs may be available.

– The Environmental Management Options Scheme (DEMOS) offers support to companies seeking to demonstrate environmental best practice. Two kinds of project will be considered:

- collaborative projects which prove the feasibility of adapted or new techniques
- projects which illustrate best practice based on proven techniques.

The scheme is aimed to cover three main areas within the environmental field:

- cleaner technologies
- recycling
- treatment and disposal of wastes and effluent. Up to 50 percent of project costs may be available.

CONFERENCE

The changing face of Europe Disasters, pollution and the environment

10th – 12th September, 1991

The University of Bradford, celebrating its Silver Jubilee in 1991, is hosting this important conference to address environmental problems currently facing Europe and the World.

The three major themes are:

- Disasters, including prevention, mitigation and emergency planning
- Pollution, including water and the atmosphere, legislation and control
- Trans-national long term issues – depletion of the ozone layer, global heating, production of carcinogens in food chains, acid rain.

Further details of the Conference are available from the University of Bradford, Disaster Prevention and Limitation Unit, Bradford, West Yorkshire BD7 1DP.

Putting pigs in the picture

C P Schofield tells how by the turn of the century, we may see video cameras in piggeries feeding information to computers which monitor the growth, health and welfare of pigs.

New work at the AFRC Institute of Engineering Research is using computers to estimate the weight of pigs by analysing images as a starting point for a wider range of applications which could help the stockman to observe and care for his animals.

Attending to the wellbeing of housed animals is the preserve of the expert stockman. Examples of his duties include recognition of individual animals, unusual behaviour of individuals or groups, detection of lame or sick animals, readiness for mating, onset of birth, shivering, crowding and signs of discomfort or stress.

Modern marketing demands accurate weight measurement

A skilled stockman can look at his animals and identify if there is anything out of the ordinary which calls for further attention, although he may be unable to describe exactly on what grounds he is making his judgement.

Further experience may enable a stockman producing fat animals for market (eg pigs), to judge their weight almost as accurately by eye alone as by weighing them mechanically. This ability is used by many producers in favour of the stressful and labour intensive alternative of putting pigs through a mechanical weigher.

However, the requirements for pigs to be reared to the very close specifications demanded by modern markets and butchers, is making it more difficult for the producer to supply stock at the optimum weight without resorting to weighing individual animals on a regular basis.

To help the stockman with these tasks calls for development of new computer-based vision sensing equipment, capable of performing tasks the stockman does already, only more efficiently. That this equipment could actively observe pigs 24 hours a day without disturbing them means that it could also enhance the welfare of farmed animals.

Image analysis opportunities in pig production

Recent advances in livestock housing, production practices and genetic qualities in Europe have ensured that farmers can more than satisfy the demand for pig meat, as far as quantity is concerned.

Politicians, the public and producers are now looking for improvements in the welfare of the stock and the stockman, and better product quality.

Paddy Schofield is a Research Engineer at AFRC Engineering, Silsoe, Bedford.

Concurrent with this change of direction has come a dramatic advance in electronics, and their application in many aspects of life.

Examples of areas where electronics are being applied in livestock production include systems to control the ventilation rates and temperatures in buildings housing pigs and poultry, and computers which control the quantity of food eaten by individual animals, each identified by ear tags containing tiny transmitters. Farm computers are now commonly used to keep records of breeding, production and feeding costs, livestock health and efficiency.

The ability to monitor livestock using automatic vision systems will open up the potential for what should effectively become 24 hour per day stockmanship.

Vision systems have been identified as having over 90 potential applications in pig production alone, and extending this to

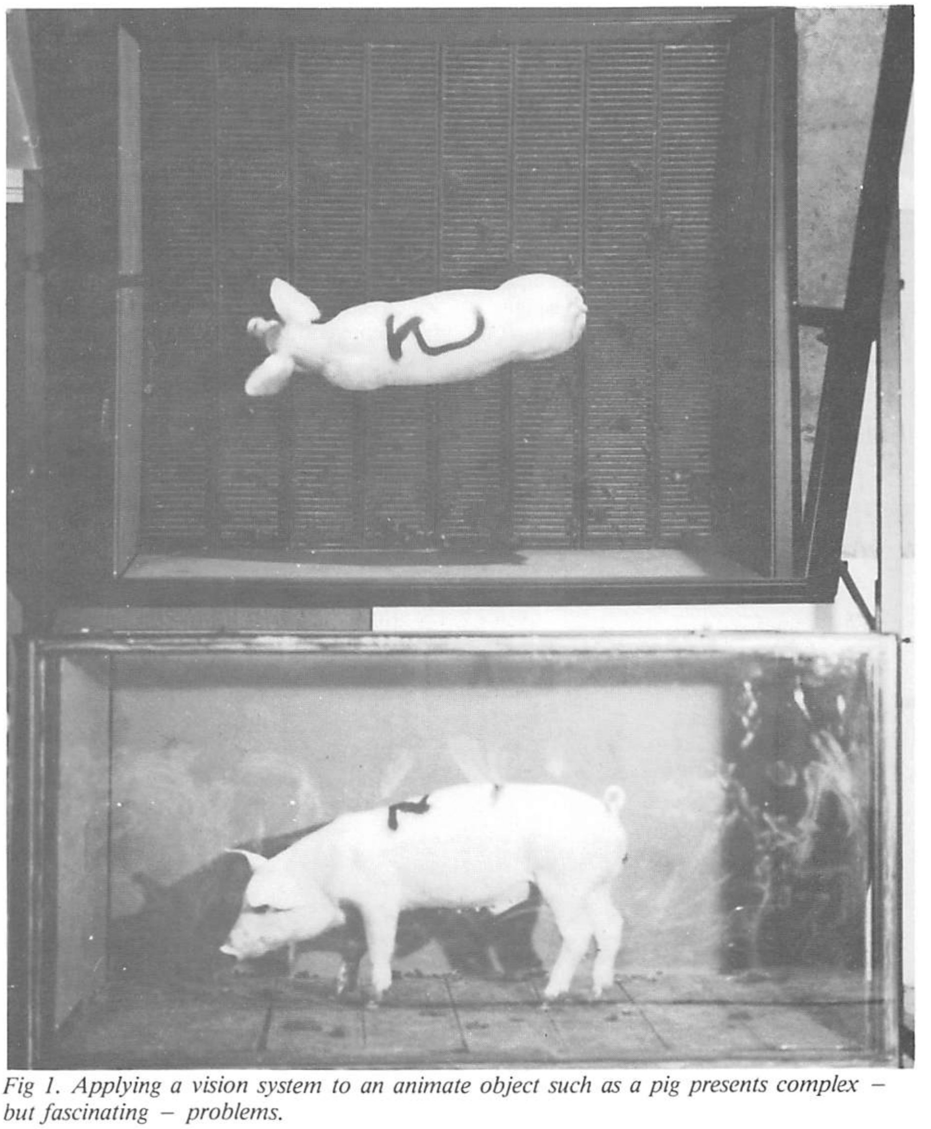

Fig 1. Applying a vision system to an animate object such as a pig presents complex – but fascinating – problems.

include all livestock shows clearly how extensive is the potential market.

Applications identified include monitoring of weight and growth rate, onset of farrowing, poor weight gain associated with illness, detection of lameness, and behavioural indicators for poor ventilation and high/low temperatures. Detection of fighting, tail biting and bullying should also be possible, all clearly illustrating the scope for future improvements in humane livestock production using image analysis as a basis for improved management.

Problems in applying vision systems

Applying a vision system to an animate object such as a pig, presents complex – but fascinating – problems. A pig comes in a range of shapes and sizes. It can continuously change its shape. It can be sitting or standing, straight backed or curved, stationary or moving. It can be a range of colours depending upon breed, and can change colour in minutes depending on how dirty it becomes. To complicate things even further, pigs are seldom kept as individuals. They are normally kept in groups of 15 to 25 and so the vision system may be expected to identify a pig on its own, or when laid on, amongst or under a group of other pigs.

There are other difficulties when using vision systems in livestock buildings.

Mechanical problems include dust, dirt and condensation, and the need for sufficient light in the region of the camera.

Furthermore, livestock not only move and change shape but they also change in morphology with age, breed and even time of day (eg depending on how full their stomachs are). This calls for more complex algorithms to relate dimensions to weight, and possibly a need to compensate for breed differences within the software of the image analyser.

A further problem which must be solved if vision systems are to be used to monitor the weights of individual animals is the identification of each animal. Electronic tagging devices will probably give us the solution, but they still need to be developed further if they are to be small, robust and reliable enough as well as economically viable for use with fattening stock.

Can vision systems be used to weigh pigs?

Development of vision systems to measure pig weight from basic dimensions forms a natural starting point for researching the principles needed to use vision processing and image analysis techniques in pig production. This application will provide a constantly updated record of body weight, giving a clear indication of growth rate, health, food conversion ratio and projected market rate, all leading to improvements in production efficiency, welfare and product quality.

There is a need for daily weighing of individual pigs, with little or no input required from the stockman or disturbance to the pig. Vision systems have this potential.

Provided that an algorithm relating dimensions to weight can be found, then a vision based image analysis system can be developed to measure those dimensions and hence calculate pig weight.

To be acceptable, the weight of each pig would need to be measured to within 5%, which is the accuracy which can be expected from conventional weigh crates.

Relationship between weight and dimensions

Accurate body dimensions and areas were measured from photographs and video recordings of pigs taken to establish the relationship between the weight of each pig and individual and combinations of body dimensions and areas.

The results, summarised in Table 1, show that there is a strong relationship between the weight of a pig and the area of a plan view image of the pig, less its head and neck (consider Fig 2). Taking the average of weight estimations from analysis of several images of a pig will enable its weight to be predicted with errors of under 5%.

Table 1. Comparison of dimensional data with actual pig weight.

Dimension	*Percentage of predicted weights having an error of less than 5%*
Plan area of whole pig	51%
Plan area less head	61%
Plan area less head and neck	71%
Tail to scapula	58%
Girth	46%
Height at back	42%
Height to shoulder	24%
Width at shoulder	24%
Scapula to snout	20%

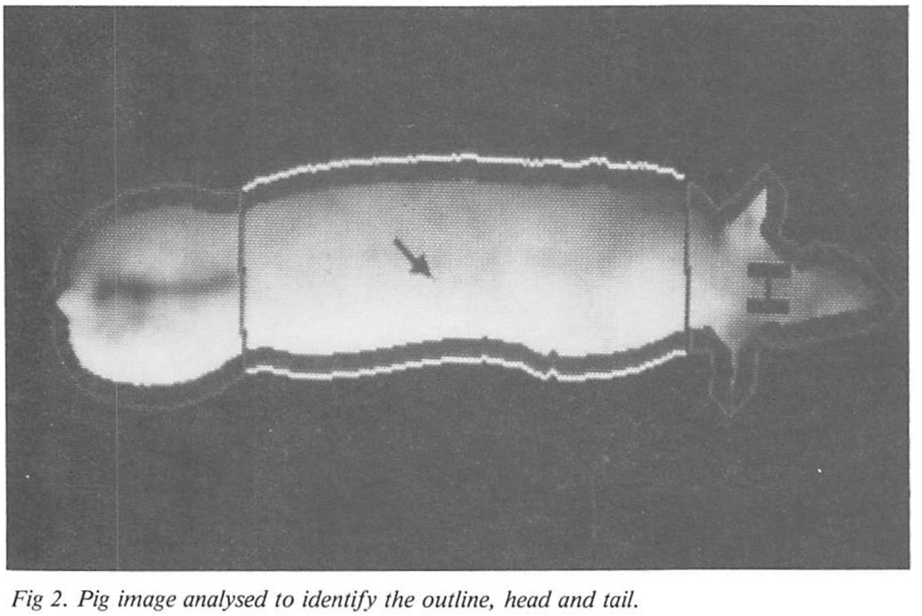

Fig 2. Pig image analysed to identify the outline, head and tail.

Future potential – tremendous

Vision systems are now being developed for use in the less than ideal conditions found inside piggeries. This involves developing and testing algorithms designed to interpret visual data collected from pigs presented to the camera at different angles, singly or in groups and under different lighting conditions. The degree of predicted and acceptable error between measured areas and weight will be determined for each condition, and the value of vision systems as livestock weighing devices established.

Further applications for vision systems in pig husbandry, and indeed in the husbandry or all livestock, are being considered, and will be the subject of future research. The number and quality of applications is enormous, and the future potential is easy and exciting to imagine.

Affiliates of the Institution

The Institute is pleased to acknowledge the support of the following towards its objectives

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Alleviating soil compaction by loosening: is it all it's cracked up to be?

S J Twomlow, R J Parkinson, I Reid

In this article, the authors point out that little is known about the management implications of the soil physical response to loosening and the associated processes of water disposal. Observations on a silt soil have shown that modification of the subsoil delayed soil drainage and led to increased soil water content and reduction in soil shear strength – ie a wetter soil, more susceptible to structural damage.

It is now twenty years since the Strutt Report (MAFF, 1970) clearly identified the problems and causes of soil compaction.

Since the early seventies, there have been considerable advances in both the prevention and alleviation of compaction. Low ground pressure vehicles, multiple task implements and even gantry systems are now familiar to, if not in common use within, the agricultural industry.

However, our knowledge of the physical changes that take place in the soil during both the compaction and subsequent loosening processes has not kept pace with implement developments in agricultural engineering. We know that untimely operations subject the soil to compaction, and we know which soils are most at risk. In addition, crop trials have shown that once such structural damage has occurred, the physical condition of the soil and its productivity can be affected for a number of years (MAFF, 1975).

Two examples of the consequences of such damage to vulnerable soils are shown in Fig 1.

Fig 1. Above: Surface waterlogging of a silty soil sown with winter wheat. Left: Incipient gully erosion in the same field as above. Even though this soil is rotated with arable and grass crops, structural instability frequently leads to surface water problems. Here winter wheat has followed winter wheat, establishment being carried out by ploughing and discing.

Greater understanding needed of loosening processes

Clearly, it is vital that we understand not only the compaction process, but also the impact of implements which are 'designed' to reduce soil bulk density and thereby remedy the problem.

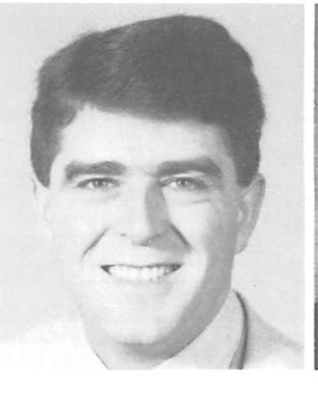
We report here on some research work carried out at Seale-Hayne on the modification of soil physical properties by deep loosening.

Loosening: questionable for silty soils

As farmers today face up to growing economic pressures and diminishing profit margins, it is increasingly important that deteriorating soil physical conditions are not allowed to cause a reduction in crop productivity. A plethora of implements is now available to the farmer for rectifying compacted soils, and each device is accompanied by claims, often ambitious, as to the potential benefits that regular soil loosening can bring in the form of reduced waterlogging and increased crop yields.

Work conducted both in the USA (Musick and Duseck, 1975) and the UK (Marks and Soane, 1987) has confirmed the limited benefit to the crop that accrues from soil loosening.

These effects have been observed to last between 2-5 years depending upon soil type,



Dr Stephen Twomlow (left), was formerly a Soil and Water Engineer at Seale Hayne Faculty Polytechnic South West, Newton Abbott and also at Birkbeck College, London. He is now with the Overseas Division, AFRC Engineering, Silsoe. Dr Robert Parkinson (centre), is Senior Lecturer in Soil Science at Seale Hayne Faculty Polytechnic South West, Newton Abbott. Dr Ian Reid (right), is Reader in Physical Geography, Birkbeck College, London. (refereed paper)

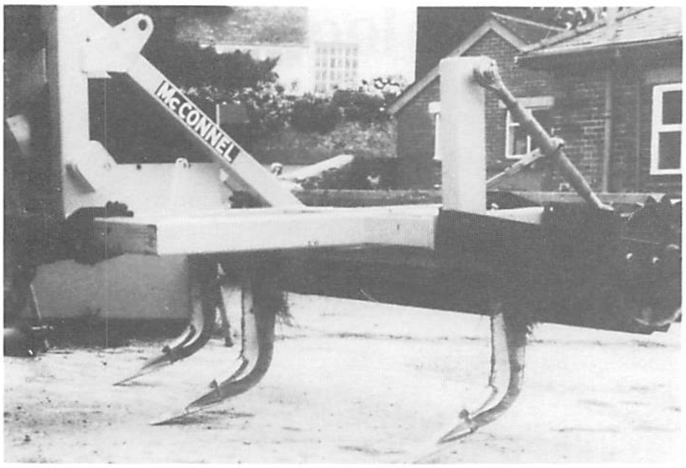


Fig 2. McConnel Shakaerator with power points. A five-legged configuration was used in the experiment described in this paper.

soil conditions at the time of loosening and subsequent field management (Soane, *et al*, 1987).

Few studies have concentrated however, on the impact that soil loosening has on the soil water regime, even though some farmers are now questioning the wisdom of drastic soil disruption as a management option, particularly for silty soils.

Investigation of a silty clay loam

Silty soils are usually highly productive, particularly if they are deep and well drained. However, the dominance of the fine-earth fraction by silt-sized particles leaves these soils prone to structural damage, especially during wet periods in autumn and spring. This problem is exacerbated in South West England by impermeable subsoils and high annual rainfalls which frequently restrict the use of these soils to permanent grassland. Even so, successful soil water management is a prerequisite if grazing or arable cropping is to be efficient and not destructive.

A field experiment was conducted in Devon on such a structurally unstable silty clay loam in order to investigate the effects on soil conditions of profile modification by loosening. The soil chosen for the trial is a member of the Sportsman Series and is formed on Devonian slate, a common soil parent material in South West England. The site at Seale-Hayne Farm had been under repeated cereal cultivation for a number of years and this continued for the duration of the experiment.

In September 1985, six drains were laid with permeable fill at a spacing of 20 m on a gently sloping (7%) site. A year after installation half the site was loosened to a depth of 0.4 m using a McConnel Shakaerator (Fig 2). The principle of action of this soil loosener is based on an off-centred weight mounted on the frame which, when driven by the PTO, causes the implement to oscillate. This vibration is designed to increase the amount of soil disturbance and reduce draft requirements. The whole site was then cultivated and winter wheat was sown.

The study concentrated on the modification of the soil physical environment and the routes that rainwater took on its way from field to ditch.

Dramatic alteration in physical properties of soil profile after loosening

It is generally acknowledged that, if silty soils are poorly managed, they will suffer rapid structural deterioration. The site chosen for this experiment was no exception, and repeated cultivation with a mouldboard plough in the past had produced a layer of low permeability at the base of the plough layer.

Such plough pans have been reported for other soils and have been shown to have high hydraulic resistance, either because compaction has severely reduced the number of large pores (ie those larger than 0.06 mm in diameter) or because the smearing action of the plough has broken the continuity of these pores between plough layer and the subsoil (Bullock *et al*, 1985). The low permeability of such pans has been shown to have an overriding influence on the process of water redistribution within the profile and to affect drainage.

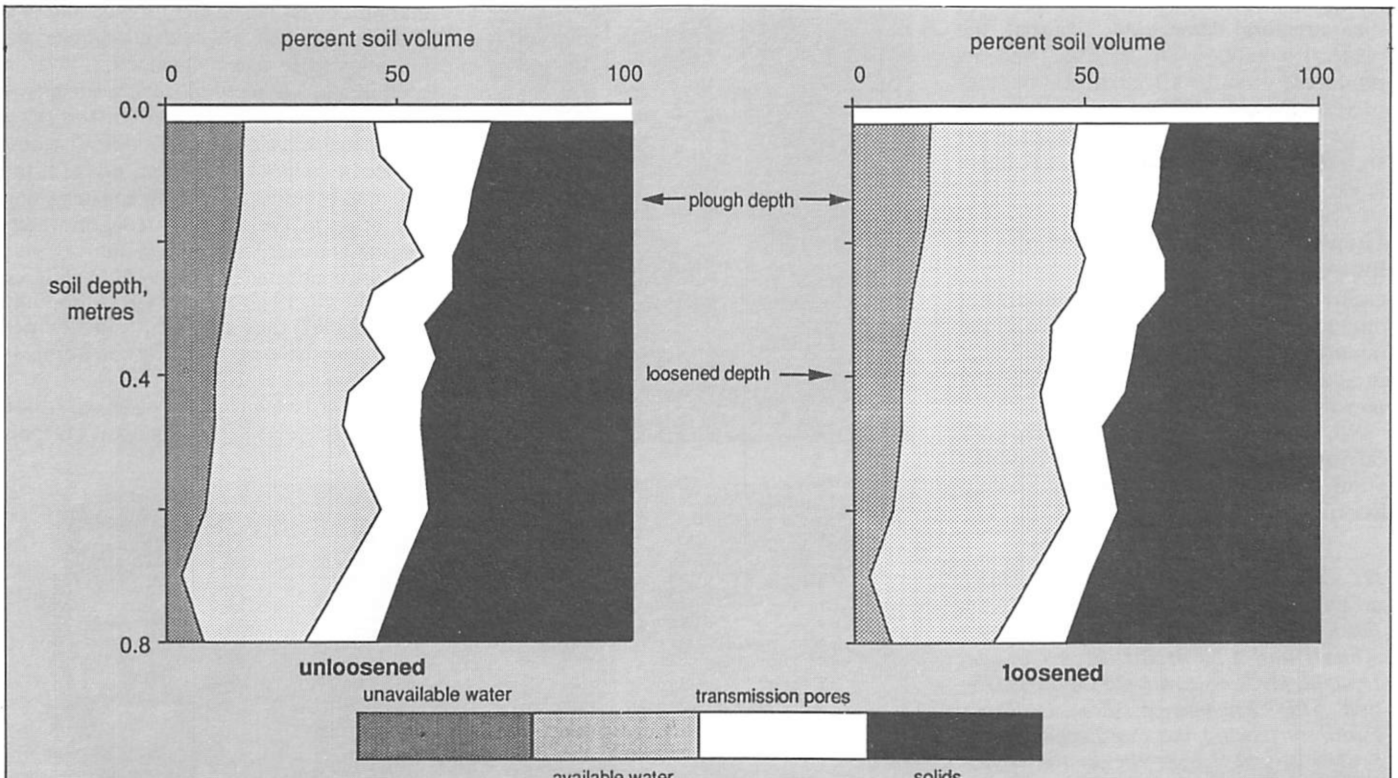


Fig 3. Soil water characteristics for unloosened and loosened plots at field capacity (winter mean water content), six months after loosening.

In order to quantify the effect of cultivation on soil physical properties, replicate 70 cm³ volume soil cores were extracted at 5 cm intervals from the top and subsoil horizons.

Disruption of a pan by soil loosening brings about a dramatic alteration in physical properties of the soil profile (Fig 3). Even after subsequent seedbed preparation, the effects of loosening are still apparent, especially between 0.2 and 0.4 m where the bulk density is significantly lower than for the unloosened soil, typically 0.85 against 1.05 t/m³ (Parkinson, *et al,* 1988). An inspection of the soil water release curves shows that the number of 'transmission pores' (pores that drain between 0 and 5 kPa tension) were significantly increased.

Fig 3 not only shows a 270% increase in transmission pore volume at the depth of what was the plough pan, but also demonstrates that even secondary cultivation of the topsoil has left the macropores that were created by loosening largely intact.

Soil loosening and the disposal of rainwater

As might be anticipated, the creation of larger pores by deep loosening alters the water transmission properties of the soil. At our experimental site, the saturated hydraulic conductivity of the shattered subsoil had increased twenty-fold, from 0.1 to 2.0 m/d (Twomlow, 1989). Changes of this magnitude have led to positive Government recommendations concerning subsoiling where subsoils are compacted (MAFF, 1982).

However, an inspection of the amount of water issuing from the drains during the winter following soil loosening shows that modification of the subsoil to improve soil water management does not necessarily give the results that are expected. In fact, loosening delays drainage, and actually reduces drainage efficiency (Fig 4).

Measurements of water in the soil reveal that drainage in the unloosened soil is dominated by movement in the cultivated topsoil, due to the fact that the poorly permeable plough pan restricts the vertical movement of water deeper into the subsoil. As a consequence, rainfall rapidly satisfies any topsoil water deficits and saturated conditions rapidly develop in the plough layer. This promotes shallow interflow to the drains through the permeable topsoil.

In contrast, greater pore continuity between the top and subsoil and a change in the nature of the pores down to 0.4 m brought about by soil loosening (Fig 3) both allows deeper penetration of rainwater and increases the temporary storage capacity of the soil considerably, so that a greater proportion of rainfall is distributed below the plough layer and into the subsoil. This leads to a delay in transmission of water to the drains.

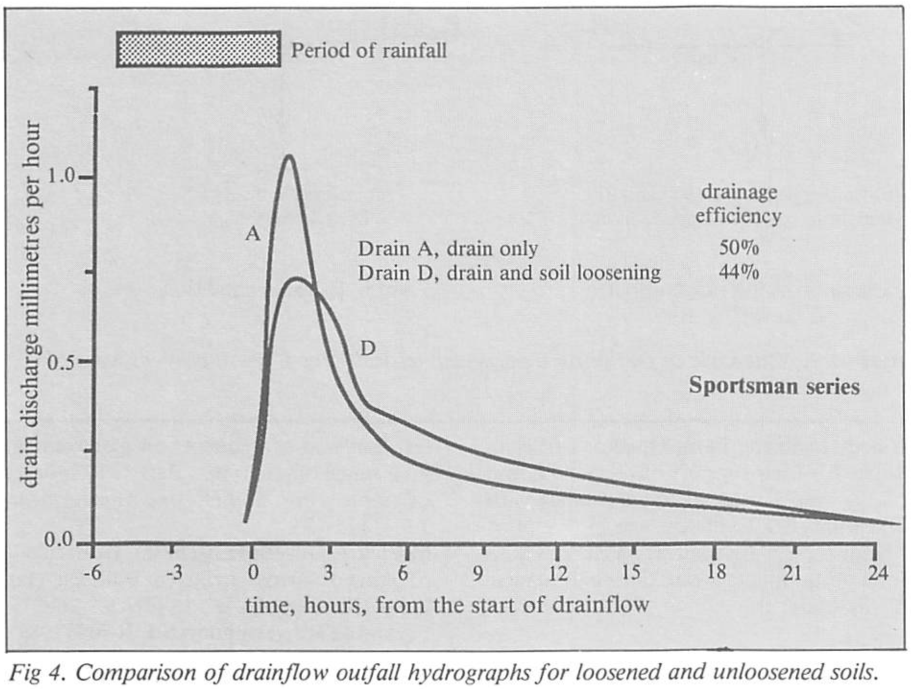


Fig 4. Comparison of drainflow outfall hydrographs for loosened and unloosened soils.

Deep cultivation can actually increase topsoil water content

It is normally assumed that drainage schemes will reduce topsoil water content, thereby improving the mechanical strength of the soil.

However, our experiments have shown that deep cultivation can have an opposite effect.

We noted these effects not only in winter (Fig 5), when the drains are running, but also in the autumn and spring. Over winter, the average water content recorded on the loosened plots was 6% greater than that measured on the unloosened plots.

This modification of the water regime is certainly not that which would be expected by either the farmer or the implement manufacturer and appears to run counter to the advice offered by the Ministry (MAFF, 1982).

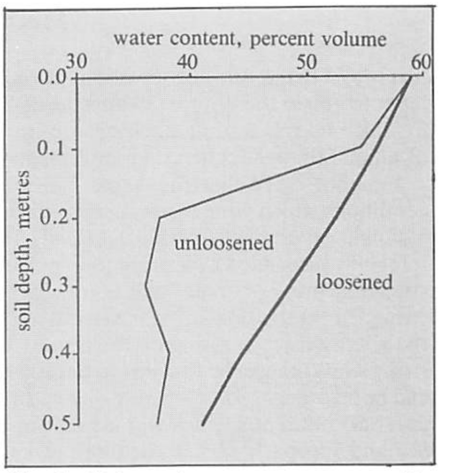


Fig 5. Volumetric water content profiles during the winter of 1986-87.

Implications for access to land

For silty soils that are naturally prone to structural damage, any changes in physical characteristics can have important implications for access to land especially during critical periods in autumn and spring. The strength of the soil will vary with water content and bulk density.

An important consequence of the changes that followed soil loosening was that the shear strength of the soil was reduced.

Fig 6 shows the general trend of increasing shear strength, measured using a hand held shear vane, with depth. Superimposed on this general trend is the divergence of the curves in the loosened but uncultivated zone, between 0.2-0.4 m.

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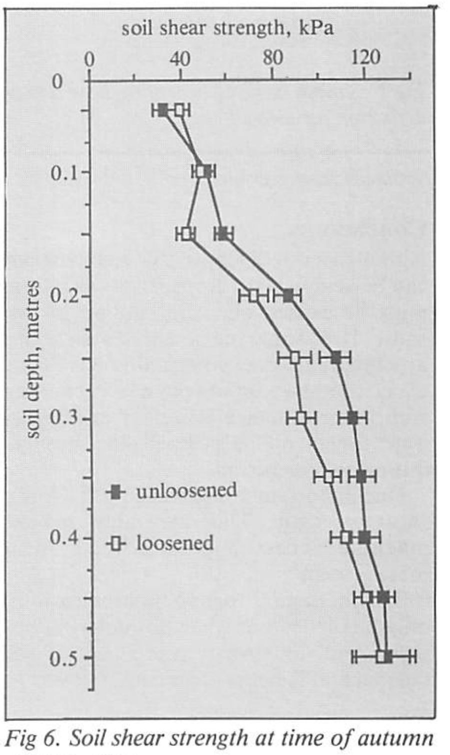


Fig 6. Soil shear strength at time of autumn sowing, 1986.

Mechanics of animal-draught cultivation implements

Sir, May I make some observations in response to David O'Neill's letter to you in the Winter (1990) issue of *The Agricultural Engineer* in which he raises some questions on my paper on the mechanics of animal draught cultivation implements?

I cannot agree that the Table 1 is misleading. The boundary conditions which your correspondent queries may be confirmed by a simple experiment (see Fig 1 below). This shows an object (the 'plough') suspended by a string (the 'pull chain') and which may be subjected to a horizontal pull *H* (the 'draught force') by a second string. In (a) the first string is vertical and its tension *P* is equal to the gravity force *V* acting on the object. Any pull *H* in the second string would cause the first one to deviate from the vertical, ie there can be no draught force when $\alpha = 90°$. In (b) the object is subjected to a horizontal pull which will increase as the angle decreases from 90° and approaches 0°. To actually achieve $\alpha = 0°$ the pull has to be extremely strong ('infinite') as illustrated in (c). The relationships are as listed in Table 1 and the boundary conditions shown in (a) and (c) may be seen to be valid.

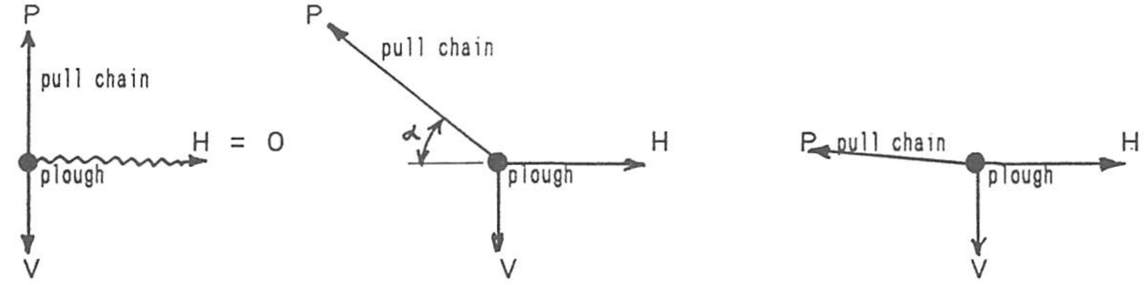
I hope I can clarify the confusion expressed by your correspondent in the closing paragraphs of his letter. The effective vertical force, which is defined in my paper, is always in practice a finite quantity. It causes the implement to penetrate to its maximum working depth and continues to exist when it gets there. It does not go away, but is fully counteracted at this stage by the upward vertical component of the pull force *P* (ie by $P.\sin\alpha$) which serves to provide equilibrium.

Your correspondent does not give details of how my paper conflicts with his practical experience so I am not able to comment on this. However, I have found the concepts which I have put forward in my paper to be practically useful in two respects.

Firstly, it has helped me to resolve conflicts of opinion such as one which exists between animal-draught practitioners and implement designers and manufacturers. Practitioners often comment on the weight of an animal-draught implement to the effect that it is 'too heavy' for an animal to pull whilst designers tend to refute any correlation. In this case my judgement, on the basis of the principles put forward in my paper, is in favour of the practitioners who are seen to have a rational basis for their opinion.

Secondly, it establishes principles of practical value to both the designer and the user of animal-draught cultivation equipment. For example, implement draught is seen to be within the designer's control whilst the operator is guided to adjustments by which draught may be reduced when necessary and proper balance of the implement for level running may be effected. In recent years I have been involved in designing and developing animal-draught cultivation equipment and have found in practice that the principles outlined explain much, without any identified conflicts so far.

Frank Inns
53 Alameda Road, Ampthill, Bedford MK45 2LA.



(a) Pull angle = 90°
No draught force possible

Not a practical condition

(b) Pull angle between 90° and 0°
Draught increases as angle reduces

Useful working range about
$\alpha = 40°$ to 10°

(c) Pull angle nearly 0°
Draught very high

Not a desirable condition

*Fig 1. Simple model illustrating how draught force **H** varies with angle of pull α for a particular vertical force V (eg implement weight) acting on an implement.*

continued from previous page

Conclusions

Although it is well known that soil loosening can be beneficial to crops, such operations must be carried out with caution in silty soils. This study demonstrates that any attempt to alleviate compaction has an unexpected impact on soil physical properties, with lower drainage efficiency and higher water content on the loosened plots throughout the winter period.

One important consequence is the lower shear strength. This inevitably reduces machine access and so affects farm management.

The message is that soil loosening must only be carried out when absolutely necessary. And, as always, prevention of soil compaction is better than cure.

Acknowledgements

The authors wish to thank the former Principal and the Farm Director of Seale-Hayne for their support of this study, and P Bugg and P Russell for assistance with field work. S J Twomlow was in receipt of a Ministry of Agriculture, Fisheries and Food postgraduate award during the course of this study.

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Mechanised rice farming in Brunei Darussalam

P W Burton describes the problems and solutions in applying large scale mechanisation techniques.

Situated on the North-West coast of Borneo, Brunei Darussalam has a land area of only 5765 square kilometres but enjoys one of the highest per capita incomes of the world, derived primarily from off-shore oil and gas fields.

Prior to 1970, production of rice in Brunei had always been somewhat below subsistence level but as the price of oil escalated in the seventies, output fell dramatically from a peak of 10,000 tonnes in 1975 to below 1000 tonnes in the space of ten years (Brunei Darussalam Year Book, 1987). This was mainly due to the rural population dropping out of farming in favour of more lucrative and secure work in the public sector.

The problem

Large scale rice farming project

Currently, Brunei Darussalam imports more than 90% of its rice requirement. Since rice is the country's staple food, the government is anxious to reverse this trend. Therefore, in view of the shortage of labour, a 350 hectare pilot project, designed by the Public Works Department and operated by the Agricultural Department, was launched in 1978 to evaluate the feasibility of large scale mechanised rice farming in Brunei.

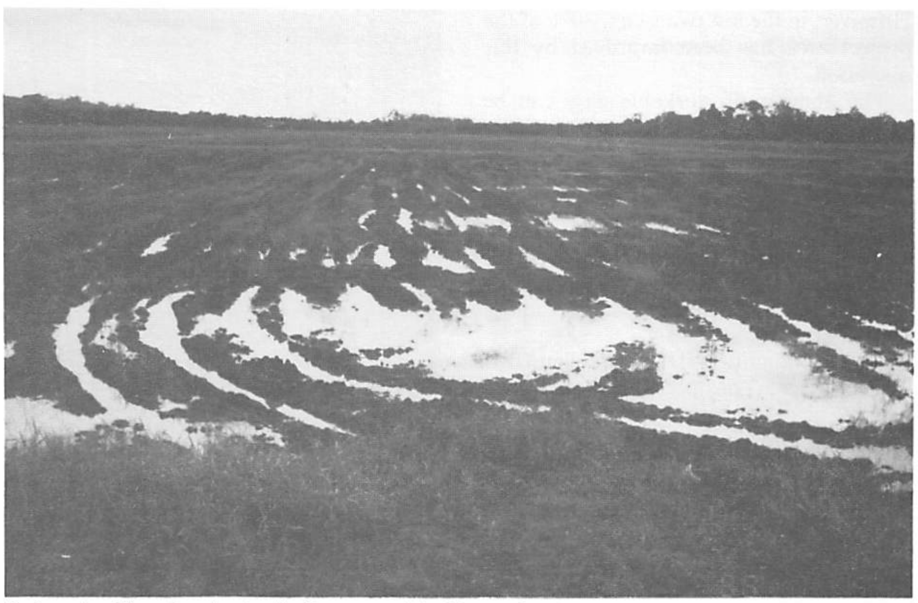
The area chosen lies 17 km south-west of the capital, Bandar Seri Begawan, on a flat alluvial plain of heavy clay, ranging from 2 to 3.6 metres above mean sea level. Prior to the development of the project, the area was water buffalo grazing land and therein lies its main constraint to mechanisation.

Former buffalo wallows persisted as soft spots, bogging down tractors and machinery

Each of the six-hectare fields within the project is pock marked with 'soft spots'; localised areas where the soil strength is virtually zero to a depth of at least 1.5 metres. Formerly these were buffalo wallow holes and water courses, which although filled during the initial field formation, have remained lower than their immediate surroundings due to subsequent settling. Any type of machine, be it tractor, half-track combine harvester or even swamp tracked bulldozer, attempting to traverse these areas will immediately sink up to the axles, requiring much time and effort to extract.

The 3000 mm annual rainfall (three times the evaporation rate) is spread fairly evenly throughout the year, therefore the low areas remain constantly under water. The soil never has an opportunity to dry out and build up any structure or strength. After three or four years of mechanised cultivations under such conditions, the 'soft areas' enlarge to the extent where land preparation by mechanical means becomes impractical and in some cases the whole field has to be abandoned.

Due to the high rainfall, there is usually little opportunity to carry out conventional dry-land-type mechanised cultivations, therefore land preparation has to be carried out under flooded conditions, even though this is highly detrimental to the machinery. At the outset of the project, 22 kW two



Before landforming (water in foreground is 30 cm deep).

Paul Burton was formerly Farm Machinery Engineer on the Brunei Government Rice Project. He is currently back in England pending a new appointment.

wheel drive tractors were used for the land work. Over the scheme's ten-year history, it has been necessary to use increasingly larger power and higher ground clearance tractors to cope with the deteriorating conditions. At the present time, 57 kW high clearance front wheel assist tractors with rear mounted rotavators are used for all the land preparation.

Land levelling programme for rice production – also eliminated buffalo wallows

Various ways of improving the performance of the tractors in these conditions have been tried using wheel strakes, cage wheels, low ground pressure tyres and bolt-on half track equipment but none was 100% successful. A solution to this problem was imperative if large scale mechanised rice production was to be at all viable and the only other alternative was to improve the soil bearing capacity to a point where conventional tractors faced no risk of bogging down. Although seemingly impractial, this is now being achieved almost as a spin-off from the recently instigated land-levelling or landforming programme using a laser guided, automatic machine control system to achieve the required precision.

Accurately levelled fields are essential for economic rice production as the depth of water on the field needs to be finely controlled at each stage of crop management. In addition to this, if the field is level, surface water quickly runs off to the perimeter drains and maximum advantage can be taken for the soil strength to recover, during the period when the field is drained for harvesting. The degree of soil desiccation during this period is directly proportional to the soil bearing capacity throughout the year (Yashima, 1985).

In Brunei's tropical climate, the number of days in the year when landforming can be carried out is very limited as the soil has to be very dry to achieve an accurate finish. However, in the last two years, 30% of the project area has been improved by this operation.

The number of workable days can be extended by constructing small surface channels to drain off standing water from the low spots. The permeability of the soil is extremely low under flooded conditions and this is therefore the only way to remove standing water. Formation of the small channels has to be carried out manually as mechanical means are not practical under such weak soil conditions.

If all the standing water can be eliminated in this way, a 5-7 day period without rain is required before land preparation for levelling can begin. Once the soil can be cultivated using disc ploughs and disc harrows, it will dry out completely within a few days, given a spell of dry weather.

Modified Rome GP Land Plane

The equipment used for landforming consists of a Rome GP 50-14 Land Plane towed by a Caterpillar D6D, both of which were purchased in 1978 for the initial construction of the project.

The solution

The Land Plane was modified in the project's workshop to make it more suitable for laser control by removing the front truck wheels and drawbar assembly together with the now-redundant rear tail boom contour sensing assembly and by fabricating a new swivelling hitch. This reduced the overall working length from 17.4 metres to a more manageable 5.1 metres.

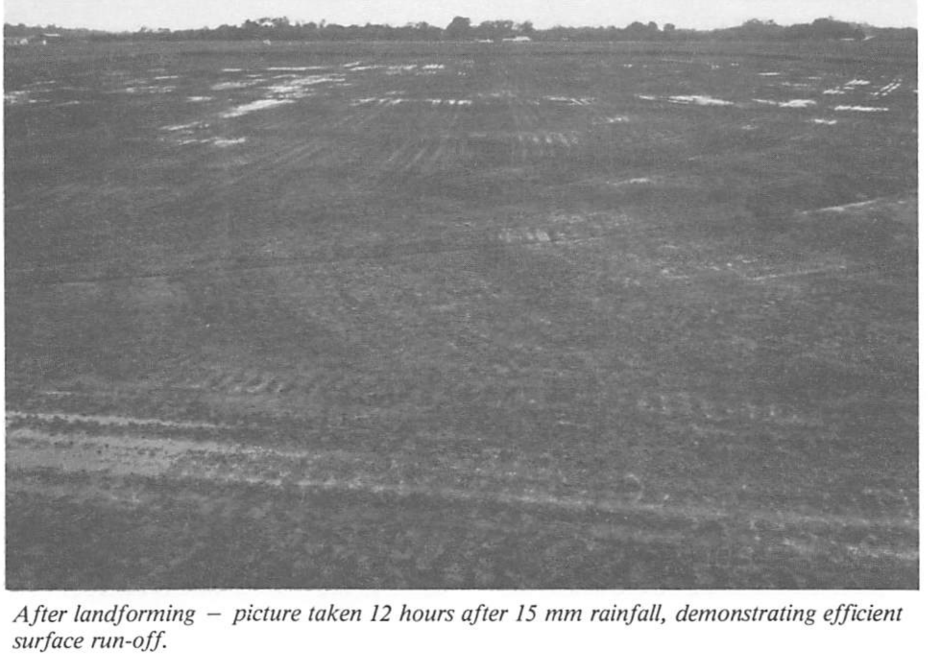
The 4.2 metre wide blade has a working capacity of approximately 2.0 cubic metres. The working height is controlled by two sets of double wheels on a common axle mounted directly behind the blade, which are pivoted up or down by double-acting hydraulic rams.

Blade setting determined from spot height readings in each field

To achieve a balanced cut and fill within each field, the average field level has to be obtained either by using conventional surveying equipment or the Land Plane itself in conjunction with the laser control system.

Spot heights, in relation to a nearby Temporary Bench Mark, are taken approximately every 20 metres and the average of all the readings is calculated. The cutting edge of the blade is carefully set to this level and the control system will then automatically maintain the blade at this height. A laser light receiver is mounted above the centre of the blade which picks up the rotating beam from the laser .transmitter mounted on a tripod at the side of the field.

Before work begins, the height of the receiver is adjusted so that the beam strikes the 9 mm 'dead band' at its centre. As the Land Plane travels across the field, an array of elements within the receiver detects whether the blade is high or low in relation to the laser beam. Any deviation from the preset level sends a signal to a bank of solenoid valves via a control box, which raises or lowers the wheels maintaining the blade at a uniform height. All that is required then



After landforming – picture taken 12 hours after 15 mm rainfall, demonstrating efficient surface run-off.

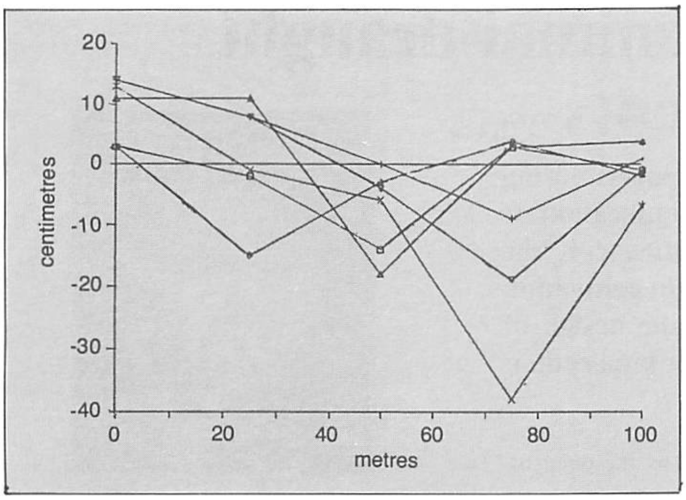


Fig 1. Typical field cross sections – taken at 20 m intervals.

is to drive round the field until the blade neither gains nor loses soil over the whole field area. The field is then level to an accuracy of plus or minus 30 mm.

Field plan and computer programme to identify optimum travel and performance

In practice, the speed of the operation can be increased by knowing the location of the high and low areas in the field. Differences of 150-200 mm (see Fig 1) over a 4 ha or even a 2 ha field are not immediately obvious but involve large quantities of earthwork.

A map of the field (Fig 2) indicating the high and low areas with vectors showing the direction and minimum distance each cubic metre of soil has to be moved, proves invaluable in this respect.

A computer programme was developed to calculate the quantities of earthwork involved for each grid sector together with the average field level and blade height setting level, taking the bulking factor into consideration, as well as the total cutting and filling volumes and the total field area.

Using this information, the best routes can be drawn up to minimise the time spent with the blade running empty or conversely travelling over high ground with the blade already full, thus making the operation as economical as possible.

Dealing with the wet spots

Landforming can begin when there are still wet spots remaining in the field. Through experience, it has been found that the best way of dealing with these is to reverse the Plane into the depression and pull the mud out onto dry areas of the field. The resulting hole can then be filled with dry soil and within 48 hours, the excavated mud is dry enough to level in with the rest of the field.

Benefits of improved trafficability and uniform crop growth

The work rate with this one machine has averaged 0.11 ha/hr. This involves cutting and filling approximately 26 cubic metres of soil per hour with a round trip per load of over 300 metres.

The benefits from the landforming operation in terms of improved trafficability of the machinery and uniform crop growth are already contributing significantly to increased rice production from the project. Additional landforming machinery is on order, including high power wheeled tractors as the prime movers, to speed up future operations.

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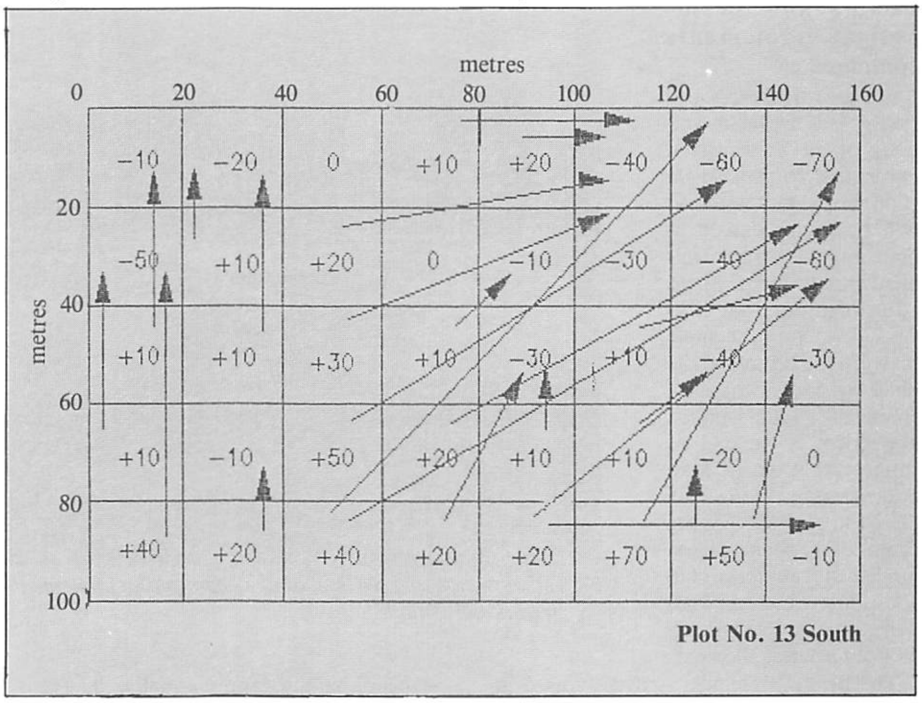


Fig 2. Map to show earthwork vectors. Cut and fill volumes shown to nearest 10 cubic metres.

Demonstration of drainage and water control

Kings Lynn, Norfolk, 10/11 July 1991

The Association of Drainage Authorities (ADA) is preparing its three-yearly display and demonstration of equipment, products and services used in flood defence and land drainage. This year, field under drainage will be included as well as matters of surface water control and flood alleviation.

The 1991 event is to be held on the 10th and 11th July on a site near Kings Lynn, Norfolk. Admission is free. This is the largest such event in Europe.

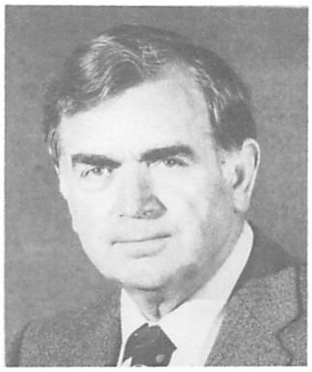
Further details will be published in our next issue.

Environmental Law

Commencing September 1991, Leicester Polytechnic is offering a two-year Distance Learning course leading to a qualification PGD/MA in Environmental Law.

Details are available from Mr Peter Shepherd, Flexible Learning Systems, Leicester Polytechnic (Technology) Ltd, Eric Wood Building, Gateway Street, Leicester LE2 7DP (Tel: 0533 554228).

The mechanics of animal-draught cultivation implements Part 2



In part 1 of this paper (The Agricultural Engineer, Spring 1990) F M Inns has explained, through the application of basic mechanics, some essential concepts influencing the effective design of chain-pulled animal-draught cultivation implements. In part 2, he deals here with the design of beam-pulled implements. Part 3 will look at the implications for harnessing.

The basic principles of mechanics outlined in the part 1 of the paper apply equally to a beam-pulled implement as to a chain-pulled implement. However, the manner of their application has to take account of a number of essential differences between the two types of implement, arising from constructional differences and associated harnessing and attachment arrangements.

Chain- and beam-pulled implements compared

The main differences are, firstly, that the beam and body of the beam-pulled implement form a single rigid body although, as will be seen later, it is necessary with most implements to provide an adjustment so that it is possible to vary the angle between the beam and the body. Secondly, whilst the chain of a chain-pulled implement is capable of supporting a tensile load only (acting along the direction of the chain) the beam of a beam-pulled implement can transmit in addition a transverse load ('shearing force') and associated bending moment.

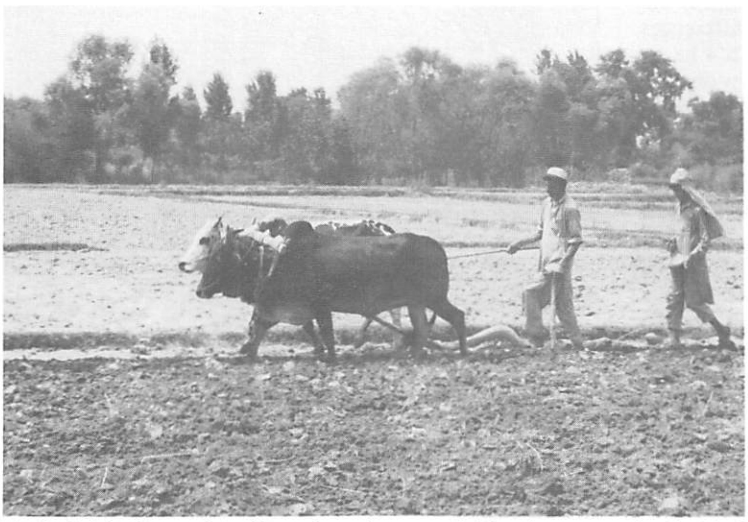


Fig 1. Cultivation and seeding using a beam-pulled implement – the 'desi hal' (= 'traditional plough').

The beam implement is usually used in conjunction with a pair of animals harnessed by a shoulder (withers) yoke. The front end of the implement beam is attached to the yoke beam. The point of attachment acts as a fulcrum about which the implement can rotate around the pitch, roll and yaw axes. This contrasts with the chain-pulled implement which has no positive fulcrum to influence these movements, causing it to be more difficult to control – a problem which is alleviated by providing it with a pair of handles with which the operator can control its orientation. The beam-pulled implement can usually be finely controlled by only one handle, used in conjunction with the fulcrum formed by the point of attachment.

Frank Inns is a consultant in machinery design, manufacture, operation and training, particularly overseas – 53 Alameda Road, Ampthill, Bedford MK45 2LA.

Fundamental force relationships

The fundamental force relationships for an implement in equilibrium, as outlined in part 1 of this paper, apply equally to chain- and beam-pulled implements. Consequently the six propositions derived from these relationships also apply equally. In detail their method of application will vary because of the differences between beam- and chain-pulled systems.

Proposition number 4 is particularly important to the economical design of an implement to meet specified targets for draught and depth of work at any value up to specified maxima. This proposition states that:

"Proposition 4. In steady work the draught of an implement is determined by the effective vertical force acting on it and the angle of pull applied to it. The draught is unaffected by the soil resistance."

Note that the effective vertical force is the sum of all vertical force components acting on an implement with the exception of that arising from the pull force. It includes (taking the downward direction as positive) the implement weight (+ve), soil force (usually +ve), forces from the operator (+ve or –ve) and support forces (–ve).

Support forces may be unintentional (eg worn shares) or intentional (control forces from depth wheels or skids or from the 'heel' of an implement).

In work, in the equilibrium state, the effective vertical force is balanced by the vertical component of the pull force.

Traditional designs point the way

Traditional practices and traditional equipment should never be ignored. They have evolved to meet particular circumstances and demonstrate, by their continuing existence, that they are in tune with the requirements and infrastructure which exist in a particular locality. It is often very instructive to examine them in detail in an attempt to identify and understand the reasons for their adoption.

The 'desi hal' (old or traditional plough) shown in Fig 1 is still used in its hundreds of thousands in many parts of Pakistan and India. It is an outstanding example of the high level of sophistication in design and construction which traditional designs can achieve. Examination and explanation of its features provide guidelines to the development of other beam-pulled implements.

The desi hal has an elegant but rather curiously shaped beam, as a result of which it is sometimes called a 'hook plough'. The body of the implement (Fig 2) is broad and long with a concave undersurface which gives good clearance under the steel share. The underside of the rear end of the body acts as a heel to provide a support force which comes into full effect when the implement reaches its desired working depth. The angle at which the body is fixed to the beam can be adjusted by a pair of wedges to regulate the implement's depth of work. The implement is made from wooden components with the exception of a simple replaceable steel share. The size and shape of the beam components are more or less standardised in a particular locality and replacement parts are usually made and stocked locally.

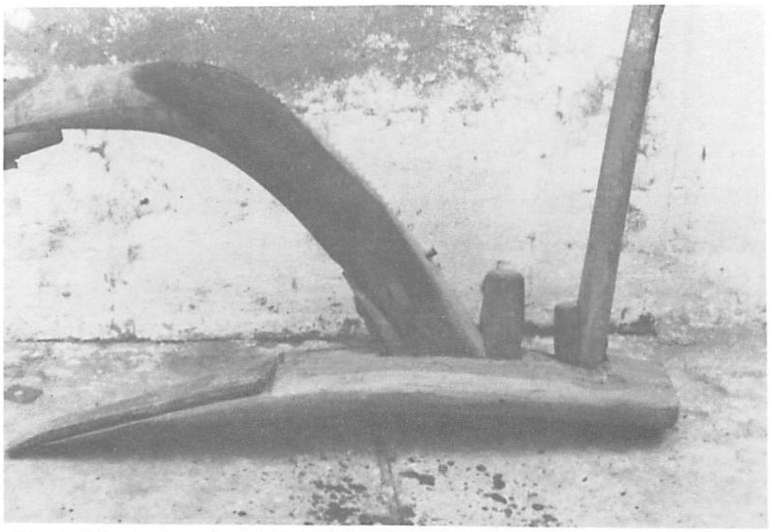


Fig 2. The body of a desi hal showing the simple share and the wedge adjustment for beam-to-body angle.

These features are discussed below in the light of the principles and propositions set out in part 1 of this paper and of other modern design theories. It should be noted that the desi hal is not truly a plough since it is not designed to turn the soil. Its purpose and action are closely akin to those of a chisel plough.

Beam orientation affects internal stresses

The force system illustrated in Fig 3 of part 1 of this paper may be redrawn as in Fig 3 of this part showing a desi hal.

In the equilibrium condition (steady work) the force applied to the implement at its point of attachment to the yoke must, as before, have a line of action which passes through the point 1 where the V_1 and H_1 forces intersect (as before V_1 is the effective vertical force and H_1 is the implement draught force).

Because the beam is an integral part of the implement's structure the centre of gravity of the plough will be a little further forward than for the chain-pulled plough, so that the line of action of V_1 (which is mainly the implement's weight) will also be a little further forward.

Comparison of the two figures shows that the line of action of the pull force follows closely the line of the long forward part of the beam. If the two lines were to coincide the beam would be in pure tension and would not have to support a bending moment.

If the initial curve of the beam were straightened out, so that it took the rather more obvious line direct to the curved post connecting it to the plough body, it would have to be made stronger and heavier to support the significant bending moment which it would then have to carry.

The relative magnitude of the bending moment at particular points in the beam is indicated by the perpendicular distance from the beam to the line of pull. Thus the hooked beam arrangement adopted for the desi hal reduces operating stresses, enabling it to be made lighter and more economically.

This is a truly remarkable example of empirical development to a high level of sophistication.

The lesson to be learnt is that stress levels and structural weight in the beam of a beam implement can be reduced by arranging the beam to follow as closely as possible the line of pull, acting between the points 1 and 2. The line of pull may be visualised as the line which a chain would take up if the implement were chain-pulled (Fig 3 of part 1).

It is convenient to adopt this arrangement since it will normally result in the beam being fastened to the implement body at a more forward rather than a more rearward point, with resulting economies of manufacture.

Implement draught is controlled by a self regulating support force

The shape of the body of the desi hal demonstrates three important operational features:

- a shallow rake angle for the share, ensuring good penetration and bursting of the soil with minimum draught
- a good clearance angle under the share, ensuring that at this point there is no support force from the soil which would oppose penetration to working depth
- a distinctive 'heel' at the rear of the body enabling a controlled support force to be generated at this point.

These features are discussed below.

When resting on a soil surface an implement is prevented from sinking into the soil by support forces which act at all points of contact. When pulled into work the soil reactions change. For a well designed implement the support forces are replaced by working forces which allow the implement to penetrate to its working depth.

The design of the implement is arranged to facilitate this action. For example, the conventional mouldboard plough is designed with a clearance or 'suck' under the share to ensure that no support force is generated at that point. In work the net vertical component of force from the soil onto the working surfaces of a plough or tined cultivator is usually downward, so increasing the effective vertical force and hence the equilibrium draught.

If the equilibrium draught is too great it may be reduced by using a steeper angle of pull or by reducing the effective vertical force.

With some beam-pulled implements (but not the desi hal) the angle of pull is made steeper by varying the point of attachment of the implement beam to the yoke beam.

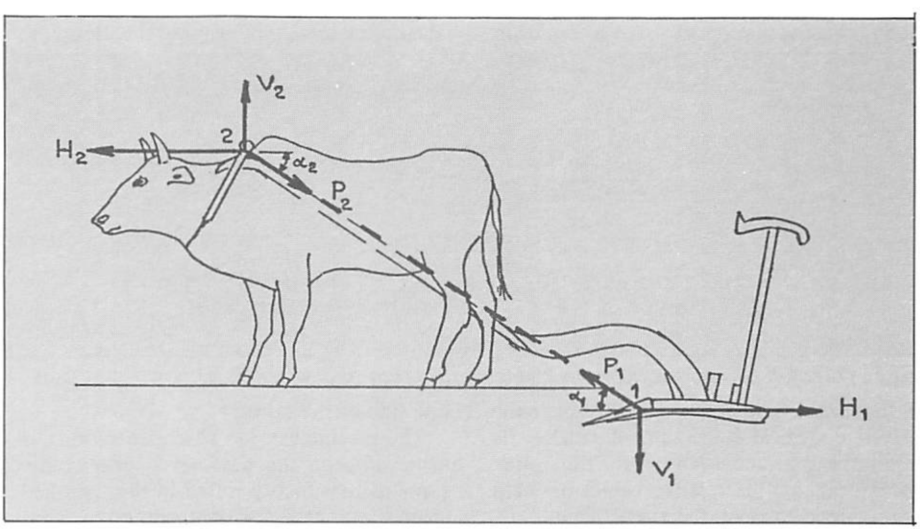


Fig 3. Fundamentals of harnessing showing the force systems acting on the draught animals and a beam-pulled implement.

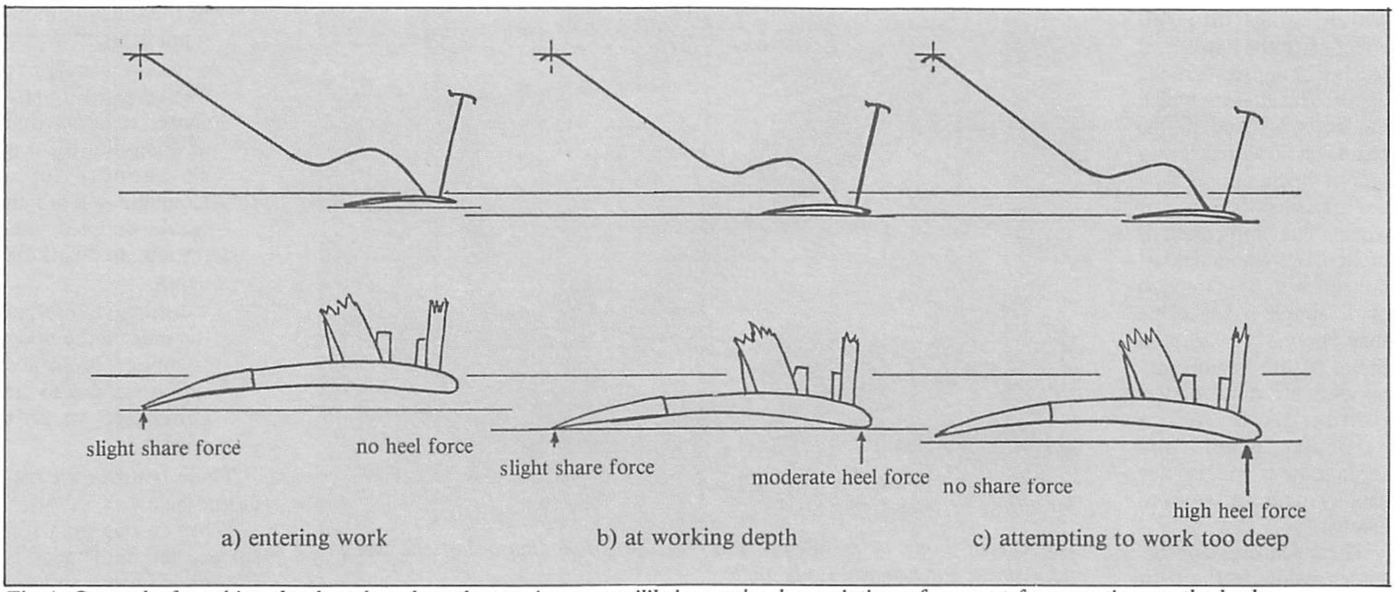


Fig 4. Control of working depth to less than the maximum equilibrium value by variation of support forces acting on the body.

In effect the beam is shortened, with consequent increase in the angle of pull and reduction in draught and in the related depth of work.

Reduction of the effective vertical force should preferably be made by reducing the implement weight, but this may not be easy to achieve. As an alternative the effective vertical force may be reduced by fitting wheels, skids, heels or other devices to generate a counteracting upward force component when they come into contact with the soil.

The desi hal makes use of the heel of the body to regulate working depth. As it moves into work it rotates about its point of attachment to the yoke beam so that the pitch of the body (the angle it makes to the horizontal) changes with depth, as shown in Fig 4. Initially it is pitched into work with no support force acting on the underside of the body, leading to excellent penetration. Its depth of work then increases until it is running level.

At this stage any tendency to go deeper is resisted because the plough will tend to rotate further and run on the heel of the body, causing a support force to build up at that point. The support force reduces the effective vertical force until it reaches its equilibrium in accordance with the implement draught, the relative values of these forces depending on the angle of pull.

Due to the length of the desi hal's body even a small change from the horizontal to a heel-down attitude will build up a considerable support force at the heel. Consequently its depth control is automatic and extremely stable.

A different working depth may be set by changing the angle between the body and the beam so that the body 'levels out' at the required new depth (Fig 5). Traditionally a pair of wooden wedges is used to make this adjustment (Fig 2).

The method by which draught, and hence depth, is controlled on a desi hal is extremely simple, economical and efficient and serves as a starting point for the design of other beam-pulled implements.

Steerability makes use of 'modern' techniques

Effective inter-row weeding requires good steerability particularly when rows may deviate from the straight and parallel due to problems arising from field size and shape, topography and preceding operations including planting.

This desi hal, which is often used for inter-row weeding, is steered easily and accurately merely by leaning the plough to one side or the other.

The mechanism by which steerability is achieved with the desi hal is exactly the same as that incorporated in the 'cranked cross-shaft' used for controlling the front furrow width of a tractor-mounted plough (Inns, 1985). In essence the desi hal acts as half a cranked cross-shaft (the half containing the upper crank).

The desi hal is free to swivel about its point of attachment to the yoke beam in a manner which is equivalent to the crank of the half cross-shaft swivelling in the ball end of the tractor linkage. Leaning the plough to one side causes the body to take up an angle to its original longitudinal direction in the same way that rotating the cross-shaft causes it to take up an angle to its original transverse direction.

Thus the plough body can easily be steered by using the single handle of the plough to lean it to one side or the other causing the body to deviate from its straight ahead alignment. The effectiveness of this method depends upon the length of the body and its ability to generate a side load from the adjacent soil. The desi hal meets both of these requirements.

Implement weight is doubly important

Implement weight has a dominating importance for two reasons. Firstly, as the principal component of the effective vertical force, it plays a major role in determining the equilibrium draught of an implement (proposition 4 above). Secondly, it affects the energy expenditure demanded of the operator, particularly in the case of the beam plough.

The beam plough is extensively used in regions where manoeuvrability and controllability are particularly important.

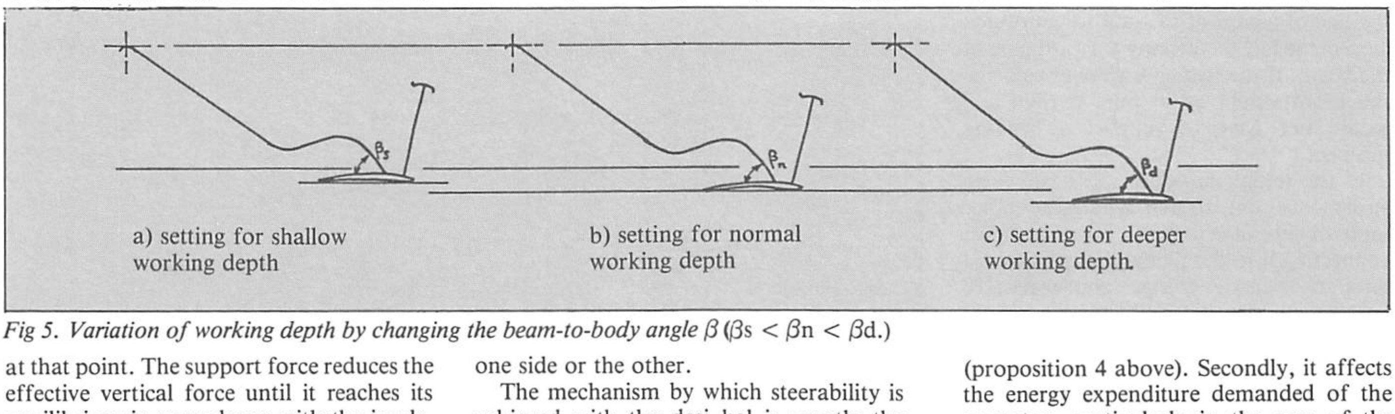


Fig 5. Variation of working depth by changing the beam-to-body angle β ($\beta s < \beta n < \beta d$.)

Hilly regions, where terracing is practised, often result in narrow, irregularly shaped areas with little room for turning and in other regions, where surface irrigation is customary, fields are often sub-divided for water control by ridges over which the implement has to be lifted.

Thus, frequent lifting may be necessary either for turning or for jumping ridges. Often the implement has to be lifted every ten metres or so and low weight is essential if the operator is not to tire rapidly.

An effort of about 120N (12 kgf) is needed to lift a traditional desi hal at the handle, using the front attachment point as a fulcrum. Other beam-pulled implements in current use (ridger, cultivator) often require more effort (up to about 150N). The farmer is not likely to accept willingly the need for any greater effort.

Thus, a reasonable design target would be a maximum lifting force of 100N to 120N for a plough, with 150N as an absolute maximum for any other implement.

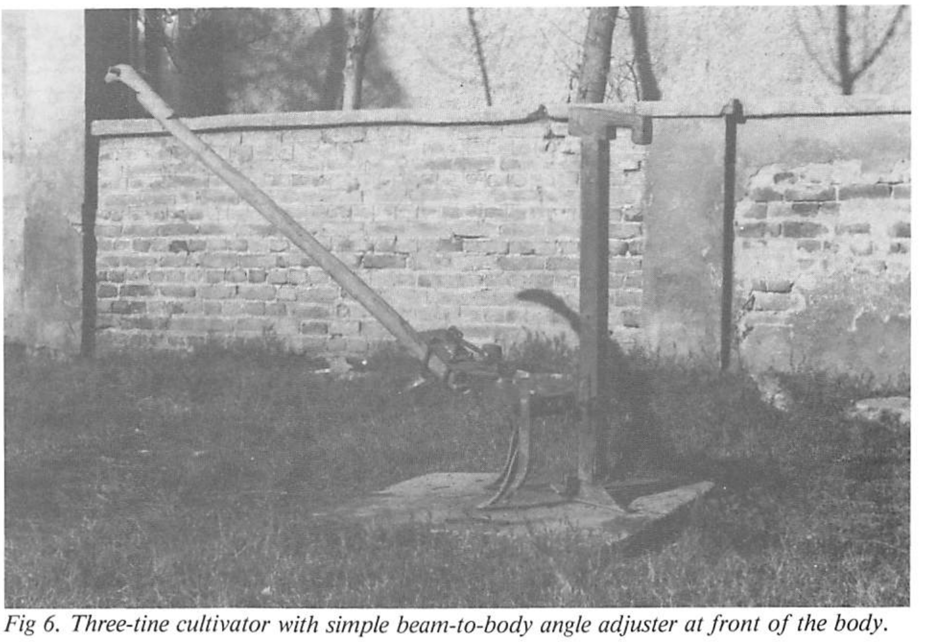


Fig 6. Three-tine cultivator with simple beam-to-body angle adjuster at front of the body.

Operational factors influence selection of implement type

Beam-pulled implements are well adapted for use by a pair of oxen or buffaloes harnessed by a traditional neck (withers) yoke. They are particularly well suited to use in small and/or irregularly shaped areas where their control and manoeuvrability is a specific advantage. Because their use involves lifting by the operator they have to be light in weight. Simple and light construction is therefore essential and their cost is modest in consequence.

The relatively low weight of beam-pulled implements leads to reasonable levels of draught, which a pair of animals can usually sustain for comparatively long periods without undue distress.

The depth and width of work is correspondingly limited so that they are less well suited to heavy soils. However, penetration in hard soils is often very good, due to the very shallow angle at which shares are set on traditional designs such as the desi hal.

Chain-pulled implements show to best advantage on heavier soils and/or where long working runs are possible. It is relatively easy to harness a team of four or more animals to a chain-pulled implement when necessary.

Compared with beam-pulled implements, chain-pulled units are relatively less easy to adjust for level running particularly if, as is often the case, their weight is greater than is strictly necessary. A rather high support force must then be brought into action in compensation, possibly upsetting the balance of the implement.

Good design makes correct adjustment possible, good training makes it happen.

Guidelines for the design of beam pulled implements

- The implement should be as light as possible consistent with its required strength and function. The effort needed by the operator to lift the implement should preferably not exceed 100N and should not in any case be more than 150N.
- To aid penetration and allow the implement to reach quickly its full equilibrium working depth it should be designed so that there are no uncontrolled support forces from the soil when in work: eg from insufficient clearance under shares and points, soil contact on the lower edges of mouldboards, etc.
- Maximum depth of work is a function of the equilibrium draught arising when there are no support forces acting on the implement from the soil or the operator (proposition 4 – see part 1 of this paper).
- It is possible to arrange for stable work at less than the maximum equilibrium working depth by:
  - short hitching, ie attaching the implement to the yoke beam part way along the implement beam, thus increasing the effective angle of pull
  - introducing a controllable support force from an adjustable skid or heel
  - arranging for a self-regulating support force to be generated as a consequence of the change of attitude which occurs with changing depth of work.
- A method of adjusting the angle between beam and body is essential if a self-regulating support force is to be used for control of working depth. It is highly desirable in other cases, to ensure level running of the implement when the working depth is changed.
- Beam weight can be minimised by arranging for it to follow closely the line of pull from the hitch point (Fig 3), thus reducing the working bending moment which it must withstand. This arrangement will also minimise the bending moment supported by the beam-to-body angle adjuster so that its size and weight may be kept low (Fig 6). Attention must be paid to the bending moment which will be caused when the implement is lifted by the operator.
- Steerability may be effected by leaning the implement to one side so that its body is angled to the direction of travel. The action may be enhanced through the use of soil engaging elements having a positive grooving action. The steerability of multi-tined implements may be troublesome.

Guidelines for the design of beam-pulled implements

The most common beam-pulled implements are:

- the breaking plough (ard, maresha, desi hal, etc)
- the mouldboard plough
- the mouldboard ridger
- the tined cultivator (usually 3 or 5 tines – scarifier, hoe, etc).

A single tined deep cultivator might usefully be added to this basic range.

The guidelines presented in the adjacent panel for the design of these implements arise from the basic force analysis put forward in part 1 of this paper (Inns, 1990) and examination, made here, of their application to a highly successful traditional implement.

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Young engineers tour of Germany, 1990

The 1990 Institution of Agricultural Engineers, Young Engineers Section tour of southern West Germany was their third consecutive annual tour and took place at a very exciting time for West Germany; official re-unification with East Germany taking place only a few weeks after the visit. The tour was organised by Andrew Scarlett and Mark Sanders. A brief report of the tour's itinerary and social activities has appeared in recent issues of the Newsletter. Here, John Kirkland gives us an in-depth look at the technical content of the tour and an insight into how agricultural engineering in Southern Germany compares with the UK.

John Kirkland

The first visit on the tour was at the Technical University of Munich. The university is composed of different engineering related institutes – the Institute of Agricultural Engineering being, of course, of interest to us.

The Institute of Agricultural Engineering is divided into two centres, one dealing with the mechanical engineering aspects of agricultural machinery and the other, situated outside Munich at Weihenstephan, being involved with the application of agricultural machinery. The Institute offers facilities for both teaching and research.

This university at Munich is one of only two universities of this kind in West Germany and caters for the southern part of the country. The government provide nearly all the funding, which remains unchanged each year. Money required for a specific purpose may, however, be obtainable from the German Research Institute.

Compaction studies and transmission research

At the **Technical University of Munich,** the degree course on mechanical engineering (with agriculture) has a duration of between five and seven years. The major options of the degree are Mechanical Engineering and Design and Development, with only two lectures per week on the agricultural engineering option. Terramechanics and transmission systems are the main subjects covered by these lectures.

There are between eighty and one hundred students per year studying the agricultural engineering option on the degree course.

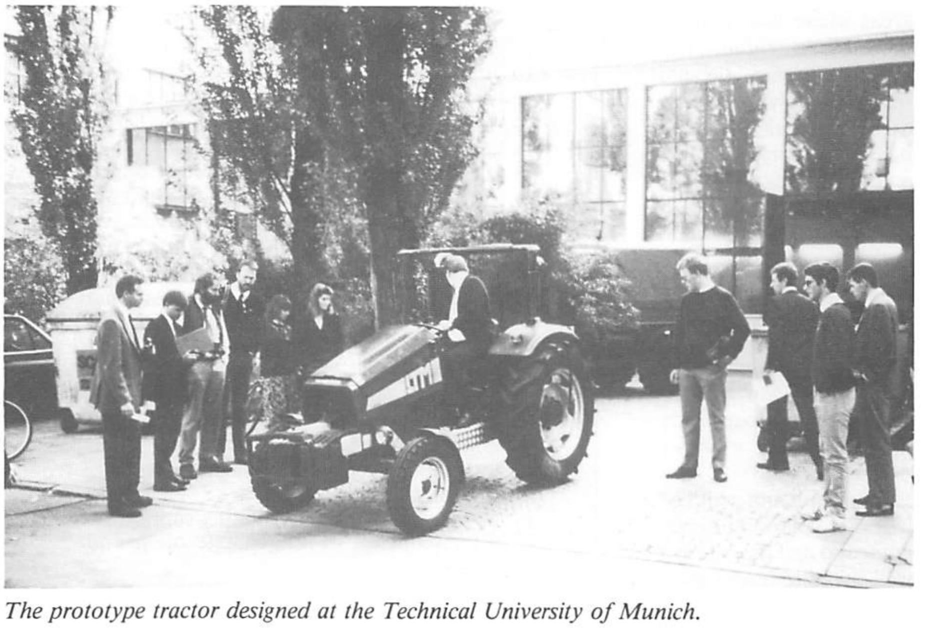
Not surprisingly, the bulk of agricultural engineering research is also based on terramechanics and tractor transmission systems. Terramechanics research mainly consisted of tyre pressure relationships with soil compaction. Computer simulation of the pressure distribution is achieved by a specially designed software package.

Work has been carried out on soil compaction by slurry tankers and also on the effectiveness of loosening the soil by two tines fitted to a slurry tanker (one behind each wheel track). Experimental work examining side forces exerted on agricultural tyres has also been carried out.

The tractor transmission research has culminated in the development of a prototype small tractor. The concept behind the design and development of the small tractor was to provide a cheap innovative replacement for old tractors of the same size.

Quietness was of major importance to the design process, hence the use of a petrol engine. Engine isolation also helped to improve noise levels with an overall noise reduction of approximately 50% over a comparable block type tractor. A CVT (continuously variable transmission) system and a belt driven pto (for cheapness) are incorporated into the design.

Transmission testing rigs have been used to study efficiency relationships between torque and speed. Factors such as oil temperature and choice of oil were found to affect transmission efficiency with synthetic oil proving to give higher efficiencies than mineral oil. A test rig to measure torques and loads on a CVT system was also developed. Axial loads were controlled hydraulically creating a relationship between hydraulic pressure and torque transmitted.



The prototype tractor designed at the Technical University of Munich.

Electronics in farming under study at Weihenstephan

The centre at Weihenstephan employs approximately 50 scientists as well as catering for approximately 15 post-doctorate students and 20 students writing theses. Its work can be split up into 3 categories – teaching, research and testing of new equipment. The testing of new equipment is funded by industry and government. The centre's main aim is to extend the use of electronics in farming with trials on new development work being conducted on actual farms under normal working conditions – not in laboratories.

An electronic system gives control of fertiliser and chemical spray distribution while compensating for tractor wheelslip. A computer logger, mounted in the cab, monitors the tractor's speed irregularities and activates solenoid valves which regulate quantities of fertiliser used. Adaptability to

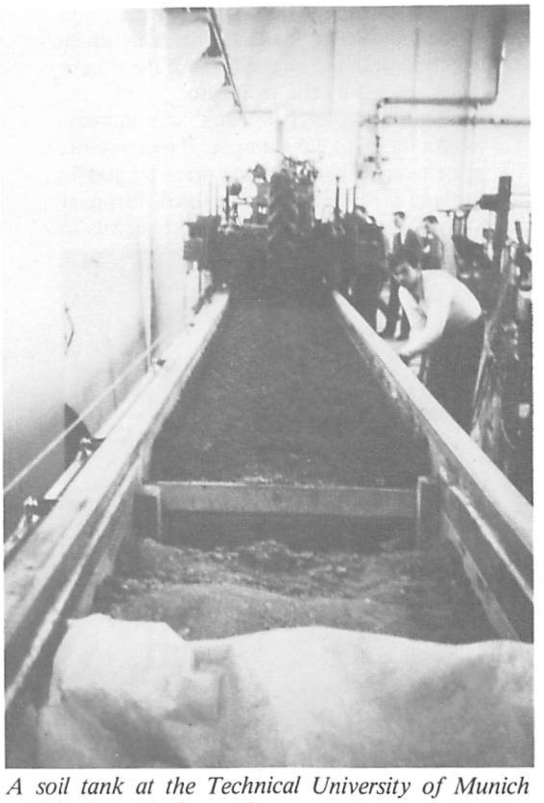
John Kirkland is a Research Engineer at the Scottish Centre of Agricultural Engineering. He was sponsored on the visit by the Scottish Branch of the Institution of Agricultural Engineers and the Scottish Centre of Agricultural Engineering. Andrew Scarlett and Mark Sanders are Research Engineers of the Vehicle Systems Group at AFRC Engineering, Silsoe.

different makes of machinery is the main problem for this system although standardisation is being worked on.

A weighing mechanism incorporated in the three point linkage of a tractor is also being developed at Weihenstephan. The development project produced three alternative systems; strain gauges fitted to the upper lift arms, load cells fitted to the connecting links between the upper and lower lift arms, and measurement of hydraulic pressure from the hydraulic rams. The load cell method gave an accuracy of ±0.5%, with the strain gauge method producing an accuracy of ±1.8%. The hydraulic method proved unreliable due to change in oil temperature. The tractor also has to be stationary and on a level site – a slope of greater than 5% creates inaccuracies. Dynamic weighing is the next step for the research project.

Another area of research at the centre concerns animal identification, automatic feeding and automatic liveweight gain measurement of animals.

An automatic milk feed/weighing station incorporated in a slatted court for bull calves provides a step forward in health and growth surveillance. Neck collar transponders or ear injection transponders are used to identify each calf individually when it steps into the feed station. The calf is given a predetermined amount of milk each day – no matter how many times the calf enters the feed station. The computer controlling the feeder can either give the calf its milk all at once or at a set amount per visit. The computer records the calf's weight each time it enters the feed station, and in the future it is hoped that with a more sophisticated electronic ear transponder, the calf's temperature can also be monitored as a progression towards automatic health surveillance.



A soil tank at the Technical University of Munich which is used for soil compaction and traction measurements.

Emphasis on quality and reliability at Fendt tractors

The second day of our tour was taken up with a visit to the family owned, world renowned, tractor manufacturer, Xavier Fendt & Co, Marktoberdorf.

The town of Marktoberdorf, below the Austrian Alps, is the headquarters of the Fendt Organisation. The Marktoberdorf factory employs 2000 people with another 1800 employed in two other factories at Kempter and Asbach-Bäumenheim. The headquarters factory incorporates tractor parts manufacture, assembly, research and development, sales and administration. The second factory at Kempter manufactures rear power lift assemblies and specialist attachments for Fendt tractors.

Fendt manufactured industrial machine tools up until 1980 when production ceased with resources being combined with tractor production. Over 60% of tractor and tool carrier components are manufactured by Fendt. The main components bought-in are the MWM engines, which were partly developed by Fendt, and the gearbox and axle castings. The more sophisticated and important machining operations, such as the machining and drilling of the gearbox castings are performed using a flexible manufacturing system (FMS) which incorporates up to one hundred drilling and milling operations. The FMS automatically checks tool condition, if there are any tools which are defective, they can be detected and replaced under computer control without disrupting output and performance.

Robotics are used for numerous machining operations. Such expensive equipment can only be justified if it runs for 24 hours per day over 3 eight-hour shifts. The assembly plant only operates one eight-hour shift/day.

Fendt claim that more efficient, sophisticated machinery centres result in better product quality providing better reliability.

The perspective taken by Fendt on market objectives is that in providing quality and reliability along with good customer relations, their product cannot fail in the highly competitive tractor market. Even though they cannot compete on the same scale of unit production as Massey Ferguson, Ford, John Deere etc, they have created their own niche by providing top quality tractors at a slightly higher price. Quality checks for accuracy of machined parts are numerous with 100% quality control resulting in 0.1-0.2% part wastage. Tolerances on shafts can be measured up to 1/5000 mm by machines which can automatically detect and adjust tolerance specification.

Fendt tool carrier offered as a system

The tool carrier tractor developed and manufactured by Fendt presently accounts for 6% of the West German tractor market. They are the only manufacturer to sustain sales successfully of this unconventional tractor. Fendt claim that its success is due to the fact that they sell the tool carrier as a system and not as a single item. Fendt manufacture and co-operate with other companies to produce implements which complement the tool carrier's versatility – this is where other tool carrier manufacturers have failed, claim Fendt.

The main advantages of the tool carrier over a conventional tractor are its superior all round operator vision, better weight distribution and four implement mounting positions. These advantages are achieved by mounting the engine horizontally under the cab. The engine's position also lowers the tractor's centre of gravity, creating better stability on slopes.

Fendt are very ecologically aware and have been for a number of years. More efficient engines, alternative fuels and control of toxic emissions are the three main areas of development. Fendt have introduced an oxidation catalyst and soot filters (coated with catalytic material) for their municipal tractor range while hoping to extend their application to other tractors. Successful trials on alternative fuels such as ethanol and vegetable oil (rape oil), have shown considerable reductions on emission levels of carbon black particles (soot) and sulphur dioxide as well as reducing levels of hydro carbons and carbon monoxides significantly. Economic viability is the only drawback, with diesel fuel being presently cheaper than vegetable oil and ethanol production.

The Fendt organisation were already preparing for the re-unification of East and West Germany. Planning for an assembly plant in East Germany is well under way.

Schlang & Reichart – specialists in forestry winches – linkage mounted, tractor mounted and full tractor conversions

It is said that Fendt is the life and blood of Marktoberdorf. The next day's visit to Schlang & Reichart in Marktoberdorf certainly proved this supposition. The main shareholder of this small- to medium-sized company producing forestry winches is one of the Fendt brothers – Peter Fendt. The company relies on Fendt to manufacture many winch parts and is situated close to the Fendt factory grounds. Schlang & Reichart are not financially supported by Fendt, however, and require to be profitable in their own right.

Established in 1945, Schlang & Reichart have produced numerous different items of equipment in the past ranging from small hand guided tractors to telescopic cranes but the development and subsequent specialisation of forestry power winches has secured a good future for them in the competitive market place. They employ approximately 60 people and expect to increase last year's turnover of £2.75m by 86% this year!

Schlang & Reichart produce three ranges of power winches – all driven by hydraulic motor via the tractor pto. Those in the smallest range are 3-point linkage mounted and can either be single or twin drum. Their loading capacities range from 4 to 7.3 tonnes for the single drum and 3 to 5.5 tonne per drum for the twin drum. This range of winches is aimed at the farmer who works in his own forest in the winter.

The mid-range winches have similar loading capacities as the three point linkage winches but they are bolted on to the tractor on a semi-permanent basis. This range was developed for the farmer who contracts forestry work in the winter but requires the tractor to work conventionally in the summer months. The units can be removed/fitted within 5 minutes and give an improved side movement stability over a three point linkage winch.

The third range is part of a system rather than an individual machine. Conversions of normal tractors to full-time forestry tractors are performed at the factory. This involves the farmer taking his tractor to Schlang & Reichart so that customisation to whatever level can be done. Full wheel, cab and engine block protection and a specialised front loader can be introduced to the tractor as well as the single or twin drum winches. A special feature of conversion is removable mudguards which prevent blockages between wheel and guard when the tractor wheels drag up branches. The whole conversion is considered permanent with the hydraulic lift arms being removed to make way for the winch and wedge plate.

Schlang & Reichart's jewel in the crown of tractor conversions, so to speak, is the Fendt tool carrier tractor with twin drum winch and front loader. The twin drum winch is mounted on the front of the tractor and powered by the front pto.

Complete conversion units can increase weight by up to 2.5 tonnes and increase the price over original tractor price by 100%. Schlang & Reichart are able to convert over 870 different tractor makes and models so that their standard winch units can be fitted. Connecting parts are designed to fit any tractor. Eighty units per year are normally converted taking on average 3 man weeks to convert.

Eighty per cent of winches sold have radio control. The radio control enables the operator to start hauling the tree up the slope immediately after the cable has been hitched to the tree. Time savings are considerable – a winch without radio control means the operator has to climb back up the slope to the tractor before winching can begin.

Demonstration of maize being harvested by a three-point linkage mounted Mengele twin row forage harvester.

Diversified range of forage harvesting machinery from Karl Mengele & Sohne

Karl Mengele & Sohne is a company with a history going back over 100 years. In 1872, a small workshop based in Gunzburg started repairing agricultural machinery. Karl Mengele took over this business in 1907 which has progressed to become a major force in the forage crop harvesting sector of the agricultural machinery market.

The main Mengele factory is situated outside Gunzburg and undertakes the assembly of forage harvesters, loader wagons, manure spreaders and tipping trailers. This purpose built factory covers 17 hectares, took 4 months to build and cost £12m, 11 years ago.

The most impressive part of the factory is the production parts store. The store measures 86 m long by 16 m wide by 22 m high. All parts are stored in crates on shelving which reaches up to the roof. Three hydraulic lifts which run parallel to each other on tracks can each automatically place a crate on a shelf space on either side of itself and at any height and length of the store. All operations are computer controlled and no personnel require to enter the store at any time, although crates are loaded by hand before entering the store. The store, which cost over £1m to build, holds only production parts, ie no spare parts, with a capacity of 7500 tonnes.

The assembly lines were working on the production of self-propelled forage harvesters and loader wagons during our visit. Mengele currently produce 6 models of self-propelled forage harvester ranging from the 6 cylinder 135 kW Deutz engined machine to the V8 325 kW Daimler Benz engined machine. The axles for the self-propelled forage harvesters are bought from Claas, as are the six row maize header attachments. The smaller maize header attachments fitted to three point linkage and trailed machines are manufactured by Mengele.

The trailed forage harvesters that are popular in the UK are not so abundant in Germany. Mengele produce between three and four hundred trailed units each year and most of these are exported to the UK and Eire. German farms are generally smaller than British farms, especially in the south, and the most economic methods of producing maize or grass silage is to use either a smaller three point linkage machine or to allow a contractor with a self-propelled machine do the job.

Mengele employ approximately 740 people with around 90 being apprentices and 20 working on research and development. Mengele have a policy where workers on the assembly plant are moved to other parts of the factory every few months. This enables each employee to be skilled in more than one job, it relieves the boredom attributed to some jobs and allows employees to mix more with other staff. Government labour offices provide financial assistance with this and another scheme which enables unemployed people to start work again with training.

Mengele are a company quite different from Fendt and Schlang & Reichart. Whereas the latter companies have based their future success on product specialisation coupled with quality, Mengele have diversified into different areas of the agricultural market. Next season reveals a new product range with the introduction of big square balers. Mengele achieved a £50m turnover last year with exports at 37% of production. Exports of some individual machines reached 90%.

Holder sprayers now available with electronic control

Holder is a company which, in the past, specialised in one area of agriculture but recently has found a larger market for their products outwith agriculture.

Holder, situated in the vineyard district of Germany, initially began to produce hand held spraying equipment designed specifically for use in vineyards. As vineyards grew larger, Holder saw the need for developing a more specialised tractor which could operate their own higher capacity sprayers in vineyards. These small, but very manoeuvrable tractors soon became used for many different purposes, such as snow blowing, grass cutting, loader work, street and path cleaning etc. So much so, that only 25% of sales now are to the traditional market outlets.

Holder currently produce 3000 sprayers and 900 tractors every year with both accounting for an equal half in the £28m turnover. Export figures are high for both sprayers and tractors at 40% and 60% respectively with Scandinavia being their best customer.

Tractors range in size from the 12 kW 2 cylinder, four stroke engine, 2WD machine to the 44 kW, 3 cylinder, four stroke engine, 4WD articulated machine. Holder initially manufactured all the main components, such as engines, axles and gearboxes, but now only 60% of parts are made by themselves. The larger tractors now use Deutz air/water cooled engines. The cylinder head is air cooled with the rest of the block water cooled.

Holder produce a varied selection of crop sprayers to cater for the requirements of different crops at all their respective growth stages. Both mounted and trailed sprayers for orchards and vineyards are air-assisted and many can be controlled from inside the tractor cab. Pressure settings, sectional boom shut-off and even sprayer compensation for tractor performance can be controlled inside the cab.

Holder employ 400 people on production and another 100 in administration. Thirty-five staff are involved with research and development.

As with all the engineering companies we visited in Germany, Holder devote substantial time and money to provide training. A three year training programme for 30 apprentices (10 each year) is pursued at Holder in a separate building away from the normal manufacturing area of the company. Apprentices are all supervised and trained in the skills requisite for the company. There are no obligatory conditions which force the apprentices to stay at Holder after training is complete, although all are expected to.

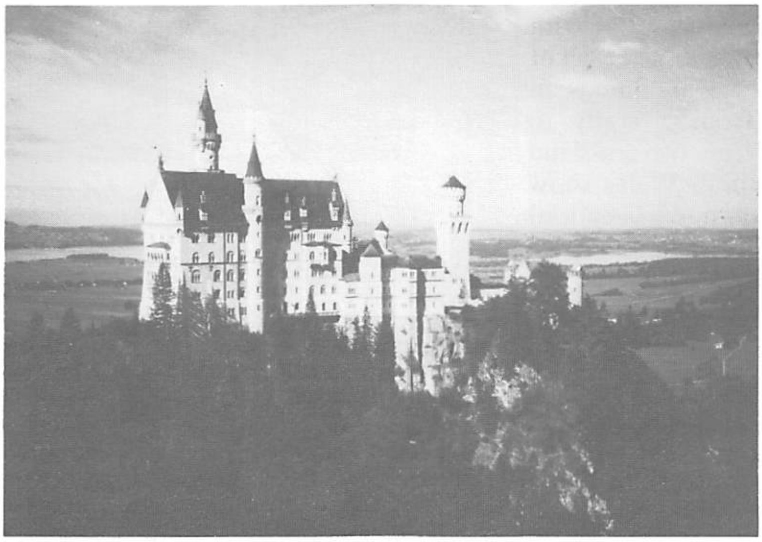
There is a significant shortage of skilled factory workers in Germany and therefore most companies regard training as crucial to the development of the company.

Institute of Agricultural Engineering at Stuttgart – strong on environment and third world interests

The 1990 Young Engineers Section tour of southern West Germany came to a close in Stuttgart with a short visit to the Institute of Agricultural Engineering, established in 1967 as a part of Hohenheim University. The Institute employs 68 people, 42 of them being paid by the University with the others being paid out of research funds.

The Institute is divided into 4 sections: Fundamentals of Agricultural Engineering – this deals with thermodynamics, power and hydrodynamics; Engineering in Plant Production – dealing with mechanics of machines and process technology; Engineering Environmental Design – farm structures in animal production and Engineering in Special Crop Production.

The West German government during the last decade has increased its international cooperation in science and technology, particularly in third world and newly industrialising countries. This is reflected in Hohenheim University's principle interests which are Bio-technology and Plant Breeding; Environmental aspects of Food Production; Ecologically adapted use of Farm Land, and Agriculture in the Tropics and Subtropics.



The 'fairytale' castle at Fussen displays a beautiful backdrop of southern Germany.

The last principle interest, Agriculture in the Tropics and Subtropics has provided a 5 year research project for the Institute of Agricultural Engineering. A joint German-Kuwaiti project on the development of an energy and freshwater autonomous greenhouse for arid zones was started in 1987. This project developed the technology to produce vegetables all year round in climatically extreme locations.

The temperature extremes from winter to summer offer significant problems for vegetable production. Results have shown that incorporation of an air bubble insulation foil and a spray cooling system in greenhouses provides an environment perfect for all year round vegetable production. The insulating material removes any heating requirements in the winter, improves the cooling efficiency in the summer by reducing evaporation and improves plant growth by diffusing direct radiation.

The spray cooling system uses spray nozzles to atomise the water within air being drawn into the greenhouse by an axial fan. The hot and dusty air is cleaned, saturated and cooled before being distributed along the length of the greenhouse through perforated polyethylene tubing which is placed between crop rows. The whole system operates on a self-control basis. The fans and pumps are automatically controlled so as to match cooling power to current atmospheric need. The operational functions such as ventilation, irrigation, fertilisation and shading are also automatically controlled. It is possible for the cooling plant to maintain an inside temperature below 35°C when the ambient temperature is above 50°C.

The project is funded equally by the German and Kuwaiti governments, represented by the Federal Ministry for Research and Technology and the Kuwait Institute for Scientific Research respectively. This project is only one in a number of cooperative research ventures between the two countries in an agreement set up in 1979.

Further development plans are to design a greenhouse cooling system which is solely dependent on solar energy instead of fossil fuels and a solar desalination plant to provide a self-sufficient freshwater supply from brackish water for irrigation.

Another research project carried out by the Institute investigated the possibility of installing an animal powered rice huller in Niger, Africa.

The animal powered huller system has many benefits – the time taken to de-husk rice is considerably lower than for human methods. It also releases workers to do other work and no special training is required to operate the huller. Simple construction allows a breakdown free operation and easy replacement of the rice huller with a cereal mill if required.

Other research areas at the Institute include combine harvester performance monitoring, crop spraying with remote controlled aeroplanes, solar drying of crops, waste management (including biogas production), harvesting and irrigation of special crops, and tractor front and rear plough combination performances.

Less financial restraints on research

One final personal observation of the research projects at the agricultural engineering institutes at Hohenheim University and the University of Munich, was that it is apparent that they do not suffer from the same financial restraints that currently burden British research organisations.

Upland pasture improvement

The effects on water quality of using two different cultivation techniques.

A M Roberts, J A Hudson, G Roberts.

Increases in upland pasture improvement could cause a deterioration in water quality and thus reduce the beneficial diluting effects of upland runoff. Increased nutrient loads in water are of concern because of the possible health implications of drinking water with enhanced levels of nitrogen and the effect of phosphorus in producing algal blooms in reservoirs. The results from a study to quantify the nutrient loads from two grassland improvement schemes in mid Wales show generally encouraging results and a beneficial effect on stream acidity.

A M Roberts *J A Hudson* *G Roberts*

The recent hot dry summers in the south and east of England have resulted in a marked increase in the growth of toxic algal blooms in reservoirs. While this is a phenomenon of lowland Britain at the moment could climate change cause similar problems in our upland reservoirs? Algal growth is sensitive not only to nutrient concentrations but also to temperature and sunshine.

The uplands of Britain, which produce abundant high quality water, cover about one third of the total UK land area. They tend to be wet, cold, have poor acidic soils and have a short growing season: because of these factors little cultivation has been attempted in the past and thus the uplands have been used mainly for grazing sparse flocks of sheep.

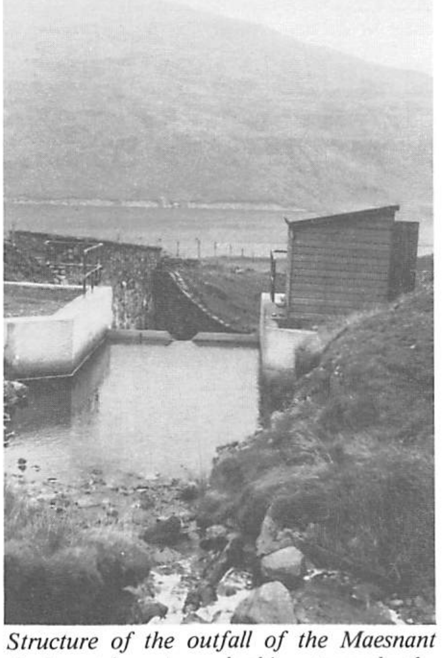
The uplands are now becoming the object of possible conflicting interests, including conservation, recreation, water supply, agriculture and forestry.

Government demands to increase upland productivity, together with EEC grants for "less favoured areas" (EEC, 1975) have meant that by the year 2025 the proportion of forested upland will be about 47% (Forestry Commission, 1977) and the amount of improved upland grassland will have been increased substantially.

Government policies have, in the past, encouraged increases in lamb production and so the amount of improved pasture in the uplands has been increased.

The amount of future pasture improvement is difficult to quantify as it is usually done on an *ad hoc* basis and in small quantities. However an estimate has been made that since the early 1950's 150,600 ha of moorland has been ploughed in England and Wales (Parry *et al*, 1981).

There now tends to be an over production of sheep meat in Europe; this will presumably lead to a decrease in the amount of grassland improvement in the future, and the land will be set aside for other uses such as afforestation.



Structure of the outfall of the Maesnant Fach catchment – looking towards the Nant-y-Moch reservoir.

High water quality required from uplands

Increasing concern has been expressed about the environmental effects that large amounts of grassland improvement and afforestation could have in upland Britain. Water quality and the amount of sediment in our upland streams could be badly affected.

Water companies rely on good quality water from these streams and rivers either to dilute water downstream, contaminated by industry, agriculture or sewage effluent, or to supply our large industrial conurbations.

With the increasingly high standards now being made mandatory by the EEC there is a fear that land use change in the uplands of Britain could result in the deterioration in water quality to the extent that extra treatments may be needed on normally high quality water.

Grassland improvements cause nutrient release while forests scrub the sulphates and nitrates from a polluted atmosphere and enhance the acidic run-off in streams. As a result of these fears the Institute of Hydrology was commissioned firstly by MAFF and then by the Department of the Environment, as part of a large project looking at upland management and water resources (Roberts *et al*, 1989a), to quantify the effect of two different pasture improvement cultivation techniques on the concentrations of nitrogen, phosphorous and potassium in the streams draining two improved study areas.

Pasture improvement methods

In the past, pasture improvement was achieved by applying lime and basic slag, together with some draining and grazing management. However, with the withdrawal of the lime subsidy in 1976 it became uneconomic for farmers to use this method.

It has been recognised for some time that the key to increased lamb production is the replacement of the existing poor vegetation

Anne Roberts is a Senior Scientific Officer and Dr Gareth Roberts is a Principal Scientific Officer at the Institute of Hydrology, Wallingford. Jim Hudson is a Senior Scientific Officer with the Institute of Hydrology, Plynlimon, Powys.

with a mix of new strains of grass seed and clover that have been developed for poor growing conditions. Seed bed preparation will depend on local conditions, but will usually involve some combination of drainage, liming, removal of the existing vegetation and fertiliser applications.

One method of vegetation removal is by deep ploughing, but fears of soil erosion and the loss of nutrients by leaching have led to the adoption of minimum cultivation techniques, the so called "Pwllpeiran Method" (ADAS, 1973). Here the vegetation is removed either by burning or by herbicidal applications and the grass seed is then direct-drilled.

The trial sites

The sites chosen to study the effects of these two types of pasture improvement techniques were located in an upland area of mid Wales (Fig 1). The first scheme was on a 1.5 ha plot in the Nant Iago sub-catchment of the upper Wye on the Plynlimon mountain range and was at an altitude of 400m. Soil samples indicated an acidic peat with a pH of 4.6 with a nitrogen content ranging from 2.3% in the upper layer to 0.4% at one metre.

The improvement was done by a local agricultural contractor under ADAS supervision. Tile drains were installed at an impervious boulder clay level with a down slope main drain and lateral drains every 10 metres (Fig 1). In the following spring the area was disc harrowed and lime, basic slag, a compound (15-15-15) fertiliser, a nitrogenous (34.5%) fertiliser and a mixture of grass seeds were applied (Table 1). Top dressings of the nitrogenous fertiliser were applied in the following two springs.

Water samples were collected daily from the main drain prior to, during and for two years after the improvement. the amount of runoff from the plot was measured at the outfall of the main drain and this was combined with the results from the chemical analysis of the water samples to give nutrient loads (Roberts *et al*, 1986a and 1986b).

The second improvement area was part of the Maesnant Fach, a sub-catchment of the Nant-y-Moch reservoir catchment. This improvement was on a larger scale than that in the Nant Iago. It is at an altitude of between 350 and 645 metres and was part of a larger land management scheme. The method of pasture improvement was similar to the "Pwllpeiran Method" as it included not only grassland improvement but also the provision of shelter belts and some recreational facilities (Fig 1).

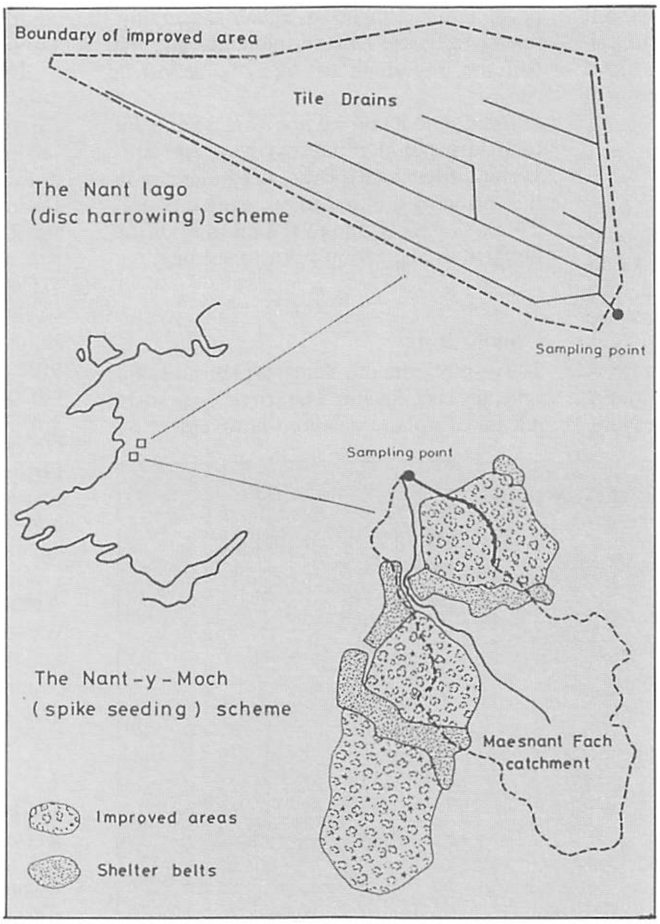


Fig 1 Location of sites

The improvement was carried out in two phases and covered a total of 26 ha. A soil survey showed a peaty soil and a pH of between 2.8 and 4.2. The improvement work was carried out by the local farmer who is a tenant of the Crown Commission. The vegetation was cut and burnt in the spring, and lime and a phosphate fertiliser were then applied. The grass seed was sown using the spike seeding method. This method lightly rotovates the ground to expose patches of soil in which the new grass seed is broadcast, the seed then germinates and eventually establishes a good quality sward. A general (22-11-11) fertiliser and a top dressing of a nitrogenous (34.5%) fertiliser was applied. Another top dressing of the nitrogenous fertiliser was applied two years later (Table 1). The second phase of the improvement was carried out in the same manner the following year.

The effects on the water quality were monitored by collecting water samples at two week intervals. The amount of runoff was

Table 1. Summary of Grassland Improvement Schemes.

Location		Nant Iago (Upper Wye catchment)			Maesnant Fach (Nant-y-Moch catchment)	
Scale of improvement		1.5 ha small plot			26 ha sub-catchment	
Cultivation		disc harrowing			spike seeding	
Fertiliser (kg/ha)	Lime	Year 1	8686	Lime	Year 1	4100
					Year 3	5800
	Basic slag	Year 1	191			
	N	Year 1	125	N	Year 1 (1st impr. Phase)	51.5
		Year 2	43		Year 3 (top dressing)	17.5
		Year 3	43		Year 3 (2nd impr. phase)	51.6
	P	Year 1	119	P	Year 1	58
					Year 3	58
	K	Year 1	51	K	Year 1	21
					Year 3	21
Results		Enhanced losses of nitrate and of ammonium after the improvement. No significant losses of potassium or phosphate.			Smaller losses of nitrate and of ammonium after both improvements. Some phosphate loss, short lived loss of potassium.	
Conclusions		Enhanced nutrient losses due to soil tillage. Gradual improvement by this method no threat to water quality. Could cause soil erosion.			The small increase of nitrate and potassium due to application and to burning. Phosphate increase due to near-surface run-off from waterlogged soils. Improvement method no threat to water quality.	

measured at the outfall of the Maesnant Fach sub-catchment and was used to calculate the nutrient loads leaching from the improved areas within the catchment (Roberts *et al*, 1989b and 1990).

Results from trials

Increased nutrient concentrations were observed almost immediately following both types of improvement. The difference was in the extent of the nitrogen released; the monthly mean nitrate concentrations are shown in Fig 2.

As can be seen, the release of nitrate is far less from the Nant-y-Moch (minimum cultivation) catchment. In fact, in the Nant Iago, the amounts exceeded the EEC limit of 11.3 mg N/litre for two weeks, with a maximum daily peak value of 18.2 mg N/litre. In the three years following improvement at Nant Iago approximately 97 kg N/ha were leached into the drain. This represents approximately 70% more than would have been lost from undistubed grassland (Roberts *et al*, 1984). It is thought that the lack of nitrogen loss from the Nant-y-Moch site was due to the different cultivation technique and to the inhibition of mineralisation as a result of waterlogging and a more acidic soil at this site.

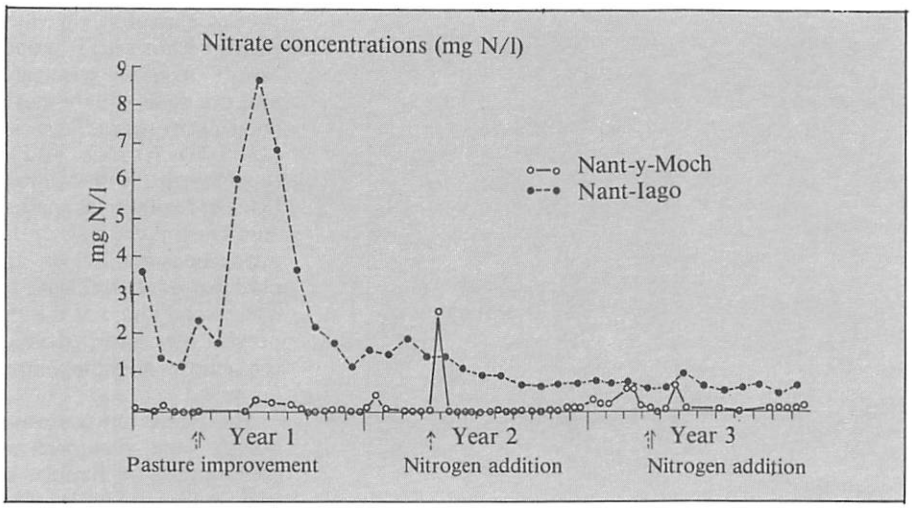


Fig 2. Nitrogen release following pasture improvement.

Differences in phosphorus release were also observed; there was no effect at Nant Iago, whereas at Nant-y-Moch concentrations increased soon after improvement from less than 0.05 mg P/litre to a peak of 2.2 mg P/litre four months later. The concentrations then decreased to pre-improvement levels after another five months.

The difference in phosphorous release between the two sites was mainly due to the type of fertiliser used. At Nant-y-Moch the phosphorous was applied as superphosphate which is readily soluble in water. The spring and summer in which the fertiliser was applied were wetter than average and so large amounts of phosphates were lost by surface runoff and by leaching from waterlogged soil. On the other hand, at Nant Iago, the phosphate was applied as a basic slag, a slow release fertiliser. This was ploughed into the soil and was much less likely to be lost in run-off.

Potassium loads did not increase at Nant Iago during or after improvement. At Nant-y-Moch there was a short lived increase in the spring of the first improvement phase. This was mainly due to the burning of the indigenous vegetation prior to seeding.

Conclusions

The results from the Nant-y-Moch study are generally encouraging. The effects on nutrient release of upland pasture improvement by this method are likely to be small.

Other research has shown that past improvement schemes, such as that in the upper Wye on Plynlimon, have had a beneficial effect by reducing the acidity of the streamflow (Reynolds *et al*, 1983). This would also seem to be the case at Nant-y-Moch where the pH has risen from 4.4 at the start of the study to 6.0 at the end of the third year.

Despite these encouraging results, it is estimated that nitrogen loads leached from improved pasture in high rainfall areas may exceed 20 kg/ha/year. These loads approach estimates given for intensively farmed areas in the lowlands (Roberts, 1987).

The conclusion here is that, at the present rate of improvement in the uplands, nutrient concentrations are unlikely to be of concern in terms of water supply. But with the deterioration in the quality of lowland surface water, with ground water polluted by nitrates, and also with the lack of recharge of these ground water aquifers due to the recent dry years, upland waters have again become a focus of some attention.

Not only is this water important for the dilution effect it has on waters downstream, but there is some renewed interest in the possibility of the establishment of regional 'water grids' if the present climate regime persists. The idea of transferring water from the uplands to South East England is certainly not new. The Times newspaper on January 4th 1876 published an article about a Royal commission Report on water pollution. It stated that "according to the Commissioners there is no necessity to have recourse to the schemes proposed for drawing water from the Cumbrian lakes - schemes which they believe to be perfectly feasible and satisfactory although extremely expensive".

Possible climatic change could conceivably mean that upland pastures could support cereal growing some decades from now. This, with all the attendant environmental and water quality problems, is a challenge for the future. Meanwhile any changes in the use of our uplands must be further monitored and interpreted, to preserve the precious resource of a generally high quality upland water supply that we have at the moment.

Acknowledgements

We would like to acknowledge the help and assistance of MAFF, the DoE, the farmers (Capt. S Bennett-Evans and Mr C Evans), plus many colleagues at the Institute of Hydrology in Wallingford and Plynlimon.

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Stock control in the 1990s

Perhaps never before in the history of Agricultural and Horticultural Dealerships has there been such a need to reconsider stocking policies within the trade. In this paper, presented at a recent meeting of the Scottish Branch of the Institution, D Francis gives us his view of how Stock Control and parts availability are being affected by advances in data communications on the one hand and the down-turn in the machinery market on the other.

It would appear that science, in the form of computers and data communications, has combined with ultra high interest rates to force dealers to review the most crippling element on their balance sheets, namely "working capital". In forcing them to review the situation it also offers a tool to help control stock levels and capital employed.

The costs of stocking

Before discussing the advantages of computing it is sensible to review the elements that comprise the cost factor of stocking. A number of years ago when the interest rates were as high as they are now, it was generally accepted that stocking costs for one year were equal to 35% of the cost of the part stocked. The elements making up this cost of stocking (stocking overheads) are:

- interest on borrowed money,
- depreciation of slow moving stock,
- pilferage

and the obvious costs of:

- heat, light, humidity controls,
- staff wages.

I doubt whether any of this has changed.

To add to our Dealers predicament another interest-related enemy has appeared in the skirmish for survival. There would appear to be a general slowing down in the trade as a result of the recession we now all find ourselves in and cuts in EEC subsidies to farmers. In short, the farmer does not have the money to spend.

Use the computer – analyse parts movement. Stock the 'Pareto' parts

All these points of which we are constantly reminded beg the question: *"what can I do to control this element of my business which is so cash hungry?"*

There would appear to be a number of recourses and I apologise in advance for the computer bias which will now unfold.

There cannot be any major argument put up against the computer on the number crunching work of stock control. The speed, efficiency and accuracy cannot be doubted and as long as daily data securities are taken, no major problems should ensue.

David Francis is UK Sales Manager for IBCOS Computers Limited.

Using the computer as a tool, then the first major step towards control of working capital must be to define the 'Pareto parts', ie the 20% of parts lines that bring about 80% of the parts sales. In summary, use the 80/20 law. These parts should be stocked at all times and show that at least 90% availability performance is maintained.

The parts record should be set to ensure that against a known sales history these parts are stocked in sufficient depth to cover the manufacturers/suppliers lead time. Admittedly the out of season stocking orders can interrupt this policy but it is possible that this discipline will change with the increase in sophistication of the manufacturers data links with their dealers.

Overnight service for non-Pareto parts

Pre-supposing we have control over our Pareto parts, the next question must be, *"what do we do with the other, non-Pareto parts?"*

Our customer has come to expect a 98% availability across the range of parts the dealer stocks. It is at this point we reach the controversial part of the debate. In essence we are going to have to educate our customers the same way our motor trade brothers have done.

Until now our customer base has had a "friendly dealer" within approximately 30 miles. As more and more dealerships close due to lack of sales and rising overheads this nearest dealer syndrome will increase in distance and the choice just will not be so diverse or so near at hand. Our customer will be forced into realising that the hitherto good deals, along with anticipated 98% availability levels of parts, has bled the dealer dry.

Should our customer be surprised – I venture not. The advent of supermarkets, buying groups and the inherent price warfare within our trade combined with competition has brought about an equalling of standards and specification. This in turn has reduced the loyalty to our customer. Fitness for purpose is surely the primary requirement of today's customer, whereas service within the price on the day of purchase is now a secondary consideration.

How do we reduce the pain experienced by our customer as we change style and attitude brought about by these commercial realities? How do we order the non-Pareto parts if we do not stock? How do we handle the damage limitation exercise?

The discipline of "just in time" has been used in the manufacturing industry for a while now and it works on the principle of having the part ready for assembly marginally before it is required. It is not held in large buffer stocks costing money while it awaits use. I put it forward for debate that our customer may now have to put up with 'marginally late' and learn to live with it or pay the price of stocking.

There are two services available currently that allow the Dealer to operate an overnight service and this in itself is the way to provide a speedy service for acquiring the non-Pareto parts that are unlikely to be in stock. They are:

- on-line data communications via a managed network,
- "next day" road link services operated by many hauliers.

Let us take each in turn: –

– data communications

In essence, dealers have been provided with this service by their main franchises. In the case of secondary franchises then there are companies who can provide the service but for each individual service a specific Personal Computer (PC) is required. The service provided works as follows:

- Enquiries and parts orders are made upon the supplier by using either a Videotext monitor or PC. The PC has a modem which translates a digital signal to analogue. This signal is sent down a local telephone line at either 1200 baud or 2400 baud (bits per second) to the nearest node on the managed telephone network (which has been rented for this purpose).
- The managed network decides the quickest route to the node nearest the supplier and the signal is received by the modem on the receiving machine. The signal is changed back to Digital and via some software that can change MS DOS communications language to be compatible with the host machine, the

continued at foot of next page

Agricultural machinery law

The process of European harmonisation leading up to 1992 has focussed minds on the need to be aware of the legal and policy developments taking place which affect our industry. EC Directives need to be converted into UK law by parliament and so provide a double opportunity to monitor change. EC Regulations, however, apply immediately, without any intervention by Westminster, and therefore require very close scrutiny in UK business is not to be caught out.

Within the UK, over the past decade, there have also been major changes in the legal obligations placed on manufacturers to produce safe machines and on farmers to protect the environment. These developments demand increased attention to detail in agricultural engineering and will continue to influence the future direction of our industry.

Below and in future issues of *The Agricultural Engineer* we will be featuring some aspects of changes in legislation and listing others. This information is extracted from a new bi-monthly publication entitled **Farm and Garden Machinery Law,** edited by Michael Darke, which follows legal and policy developments as they happen, in the courts, at Westminster, in Brussels and in Strasbourg. The object is to make the items relevant, readable and concise.

Our thanks go to Farm and Garden Machinery Law for allowing us to reprint these abstracts. More detailed information about these abstracts and listed subjects can be obtained by writing to Farm Law Publications, 6 Buckingham Gate, London SW1E 6JU. (Subscription: UK – £40.00/annum; overseas – £45/annum).

Operators' Manuals

The Agricultural Machinery and Implements Standards Policy Committee of BSI have revised and re-issued the "Guide to Information, content and presentation of operators' manuals provided for tractors and machinery for agriculture and forestry". The 1982 edition needed an up-date at least to cover the fact that designers, manufacturers and importers now have to take account of the uses of the product which are "reasonably foreseeable". This includes closely related uses and maintenance and storage hazards.

The operators' manual is part of the product. It is therefore to sell a defective product if the manual gives faulty information or is not issued to the customer at the time of sale. The Guide gives a good indication of the recommended style and technical content of operators' manuals but wisely it does not aim to provide sample wordings. Each product requires its own treatment.

The British Standard for operators' manuals (BS 5401) came into effect on 1st September 1990. Copies may be obtained from HMSO or from BSI Sales, Linford Wood, Milton Keynes MK14 6LE.

Trailer brakes must work

If a trailer has brakes, they must work effectively even if they are not actually legally required to be fitted in the first place.

This is the effect of a recent ruling by the Court of Appeal in a case involving a trailer weighing less than 750 kg in gross axle weight which had a defective braking system. Such a trailer is not legally required by the Road Vehicles (Construction and Use) Regulations to have brakes fitted and it had therefore been argued that no prosecution should have been brought. The Court of Appeal dismissed this argument saying that it would be "absurd" that defective brakes could not be the subject of prosecution unless the trailer in question weighed more than 750 kgs.

Interested organisations around Europe are being consulted by the Commission about a draft Directive to deal with the harmonisation of laws relating to braking devices used on agricultural trailers and trailed agricultural machines and implements. The Directive will be in the form of an amendment to Dir 76/432 which lays down common levels of braking efficiency for agricultural and wheeled tractors.

Other items covered in recent issues include:

Mobile Machinery Directive – Draft
Product Safety Directive – Draft
Reform of Trade Marks Law
Tractor Cab Regulations – Amendment
Road Vehicles Regulations – Prop'd Amend'ts
Radiation Risk on Combine Harvesters
Distribution Agreements
Service Liability Directives
Unfair Contract Terms Directive – Proposal
Safety of Garden Tools
Disposal of Batteries
Avoiding the Receivers Maw
Duties of Terminated Dealers
Early Day Motion on Farm Safety
Exhaust Emmissions Protocol
Professional Qualifications Directive
Goods Vehicle Operators' Licence – Draft
UK Farm Unions – Tax Submission.

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enquiry is made on the records of the necessary files.

- To return a signal the reverse process is undertaken.

The communications software supplier is usually tied in with a telecommunications network operation. Household names being Istel, Prestel and Fastrack. The cost of a call on this service is at local rate and a budget figure would be circa £3 per hour. At 2400 characters per second you send a lot of information down the line in 1 hour!

A major influence on the cost of the use of the service is whether data is prepared "on-line" or "off-line", to use computer jargon. In essence this means either being connected to the network whilst preparing and sending data (on-line) or preparing it all on PC and only sending it when ready (batch or off-line).

LEC (Leading Edge Communications), a sister company of the IBCOS Computer Group, has been set up to be an independent supplier of communications software for dealers using the off-line techniques via a clearing house facility. Added to this only one PC is required irrespective of the number of manufacturers using the system. This facility is not available via a Videotext terminal – it has to be a PC.

– next day delivery

Despite the apparent chaos on our roads, this facility of getting a parcel anywhere in Britain is about 85% successful. The only real exceptions are the Scottish Highlands and deep south west. Costs are not extortionate.

Advise the customer – 'in stock' or 'next day' (guaranteed)

Having suffered the ignominy of not having a particular part on the shelf the dealer can, using the two facilities explained earlier, inform the customer of the following. That the part is or is not in stock, or is not on order and if the latter when it is likely to be in. The dealer can also virtually guarantee a next day delivery and, close a sale on a part that is not in stock!

It is a strange irony that by holding so many parts in stock our dealers are not as thick on the ground as they were. However, although this has meant extra travelling for some customers, it has enabled the remaining dealers to live and fight another day.

Has the worm turned or will the remaining dealers still try to offer a high 90% availability across their parts range? Only two things will change any thinking on this. They are, in my opinion, a marked improvement in on-line data communications between dealer and supplier, and here I include the short line manufacturers too. The other must be the reduction in interest rates and thereby a reduction in stocking costs. If both these aspects were addressed immediately it would still leave all the other overheads of stock to fund. Market forces will dictate the outcome and only time will determine the dealers' verdict.

Lister-Petter powers cavity sludge pump

The TX3 diesel engine from Lister-Petter, a Hawker Siddeley company, has been specified by Agrico Engineering Limited to power its fast tow progressive cavity sludge pump.

The pump is designed to handle thick sludge for deep well emptying and general sludge distribution around sewage treatment works. It is also capable of pumping at high pressures for use with hose reel irrigators or irrigation pipes for the distribution of environmentally acceptable digested sewage sludge fertiliser on agricultural land.

Power is provided by the axial fan-cooled three cylinder TX3 diesel engine producing 40 BHP at 2500 rev/min, fitted with a heavy duty clutch with integral gearbox. For mobility the pump and engine unit is mounted on a robust fast tow road trailer which is easily manoeuvred on site by using extending handles.

The TX3 is one of a wide range of air and water cooled engines manufactured by Lister-Petter Ltd, Dursley, Glos GL11 4HS. Tel: 0453 544141.

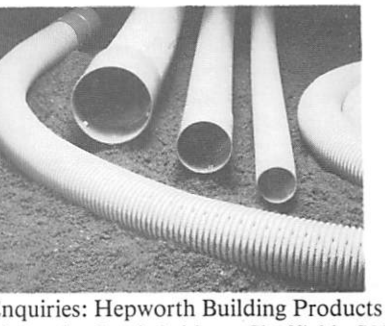
Plastics land drainage system from Hepworth

Hepworth Building Products has published new literature giving comprehensive details of its recently launched Oakland plastics land drainage system.

The Oakland name has been synonymous with land drainage for over 50 years. The plastics system is designed to complement Oakland clay ranges, giving the user a choice of materials and enabling specification closely to match soil and installation criteria.

Included in the leaflet are notes on land drainage applications in agriculture, gardening, and sports and leisure environments.

Pipe diameters, coil lengths and details of couplings are provided, together with information on installation.



Enquiries: Hepworth Building Products, Hazlehead, Stocksbridge, Sheffield S30 5HG. Tel: 0226 763561.

One man can cut and feed silage with the new Shear Grab feeder from P J Parmiter and Sons Ltd, Station Works, Tisbury, Wilts.

With a fully integrated hydraulic system, the new feeder can be operated in conjunction with the Parmiter Shear Grab and requires no extra hydraulic services from the tractor, thus keeping fitting costs to a minimum.

New specialist fruit chambers

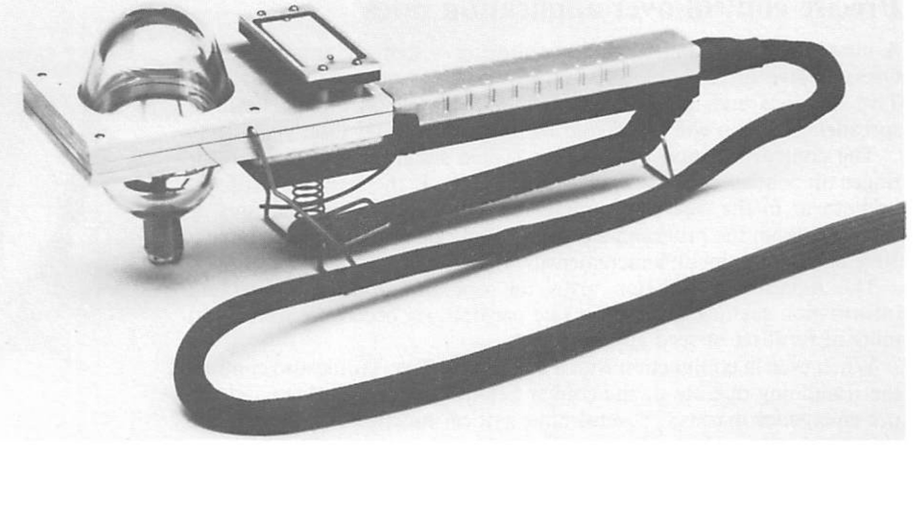
The Analytical Development Company Limited (ADC Ltd) has developed a range of fruit chambers, designed for measuring respiration, photosynthesis and transpiration in many kinds of developing fruit.

For use with ADC's LCA range of portable plant physiology measurement systems, the chambers enable researchers to monitor several metabolic parameters during fruit growth.

Each chamber is lightweight, fully portable and incorporates sensors which measure inlet/outlet humidity, leaf temperature, chamber temperature and incident photosynthetically active radiation. An integral impeller reduces the build up of concentration gradients in the chamber and a radiation shield minimises external heating.

Chamber sizes are available to suit individual requirements from 50-190mm diameter.

ADC Ltd, Pindar Road, Hoddesdon, Herts EN11 0AQ. Tel: 0992 469638. Fax: 0992 444567.



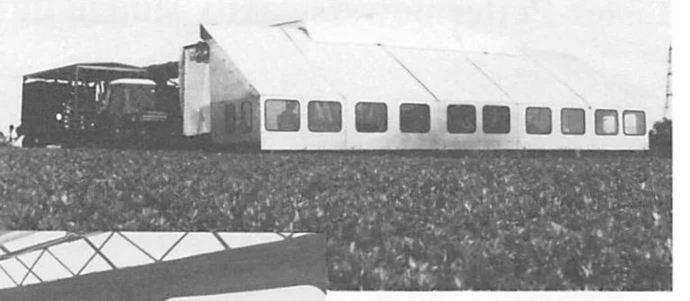
Institution of Agricultural Engineers

1991 Annual Convention

Wednesday, 8th May, 1991

In-field celery processing involves Stewart Gill conveyors

Stewart Gill & Co Ltd, manufacturers of conveyors and process plant, report a highly successful application of their Closedtrack conveyor in a pioneering development of agricultural engineering.



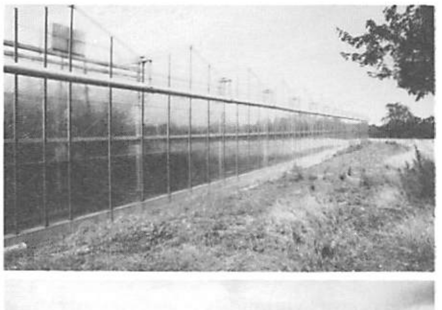
Working closely with specialist celery growers, G S Shropshire & Sons of Ely, the latest development is an in-field processing unit.

Tracked vehicles fitted with large front canopies provide cover for the hand pickers who load the celery into the inverted Closedtrack conveyor mounted along the forward edge. The conveyor, forming a closed loop round the canopy, carries the crop up into the integral cleaning and packing station.

This concept of in-field processing is reported to be showing a 25% improvement in volume efficiency. Speed of crop delivery is also greatly enhanced through elimination of the double handling inevitable in conventional processing lines.

The equipment operates 5-6 days a week during the intensive cropping season from July to mid-November. In this period, growers G S Shropshire expect to pick 60,000 head of celery per day.

Stewart Gill are at 87/89 Farnham Road, Slough. Tel: 0753 75115. Fax: 0753 692322.



New from Cambridge Glasshouse Co

Cambridge Glasshouse Company (Tel: 0223 262395, Fax: 0223 262713) has recently introduced two new additions to its range.

The Cambridge Venlo (above) is the only British offering manufactured to British Standards. Built to BS5502, it is specifically designed to withstand the extremes of British weather. BS5502 takes account of wind and gust speeds in different parts of the UK, and snow loading in valley gutters so the Venlo can be safely located in high-wind areas and on exposed sites.

The Cambridge 644 Clearspan (below) is also built to BS5502. It has been designed to allow for fast erection as well as offering superior roof ventilation and increased light transmission.

New DATUM level instrumentation

A range of level measuring equipment aimed at the Water Industry has been launched by ABB Kent Taylor (Tel: 0480 75321).

The Datum family of submersible level sensors and associated electronics addresses today's problems in water level measurement and telemetry. Problems like the lack of local electrical supply, the increasing need for low maintenance and low cost of ownership, the use of SCADA or radio transmission and the very topical requirement of ac modems for rented telecom lines can all be solved with the Datum system.

The Datum system is designed to have a high degree of noise immunity. The electronics units are environmentally protected to IP55 and all wetted parts of the sensors are approved by the National Water Council for use in potable water.

Precise control over application rates

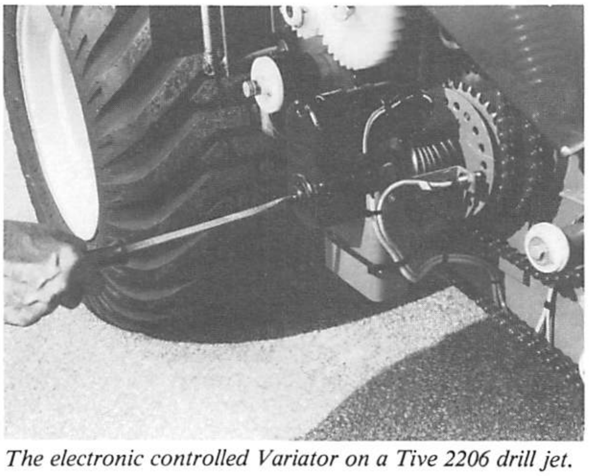
A new electronic control and monitoring system is announced by Overum Tive Ltd. The system – the Variator – can be fitted to the Tive drill jets and large capacity trailed Tive jet pneumatic fertiliser spreaders. Later it will be offered for the mounted fertiliser spreaders.

The control function of the Tive-Tronic system gives the operator finger tip control over the application rates – ie the seed, or fertiliser, or both as in the case of Combi-drills. Once calibrated, increases or decreases from the programmed application rates can be made at up to 30% either way, in 10% increments.

The monitoring function gives the operator constantly updated information such as application rate per hectare, hectares covered and units of fertiliser or seed applied.

When used in conjunction with a drill-jet the Tive-Tronic also controls the tramlining operation, the coulter beam, the bout markers and the pre-emergence markers. Several other critical functions of the drill are also constantly monitored.

Overum Tive Limited, Rutherford Way, Fison Way Industrial Estate, Thetford, Norfolk IP24 1HA. Tel: 0842 766111, Fax: 0842 755886.



The electronic controlled Variator on a Tive 2206 drill jet.

THE INSTITUTION OF AGRICULTURAL ENGINEERS

Secretary / Chief Executive

The Institution of Agricultural Engineers is the professional body for engineers, scientists, technologists and managers in the agricultural and allied industries including forestry, horticulture, food processing and agrochemicals.

The Institution is administered by the Secretary and a small staff from offices in a rural area of Bedfordshire.

The position requires a mature person, with administrative / managerial experience and financial understanding in an engineering organisation or professional institution.

For further details apply to: – **The President, IAgrE, Douglas M Walker,**
(marking application: **John Deere Limited,**
"Private and Confidential") **Langar, Nottingham NG13 9HT.**

Institution of Agricultural Engineers

Second International Conference

2nd – 5th September, 1991
Robinson College, Cambridge

Engineering the Rural Environment

Cancelled

It has been decided to cancel the 1991 International Conference. This decision has been taken with considerable regret but the indications are that it could not have received the support necessary to ensure overall success and fulfillment of objectives.

Don't forget!

Institution of Agricultural Engineers

1991 Annual Convention

Wednesday, 8th May, 1991
University of Newcastle upon Tyne

Agricultural engineering and the environment

See inside front cover for details

INDEX FOR VOLUME 45

Many members have queried the need for an annual index – recent issues are generally close to hand and details of contents still in the mind.

A five-year index is proposed by the Editorial Panel and, as a starting point an index for Volumes 41 to 45 is being prepared and will be published later this year. Thereafter there will be an index published every fifth volume.

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