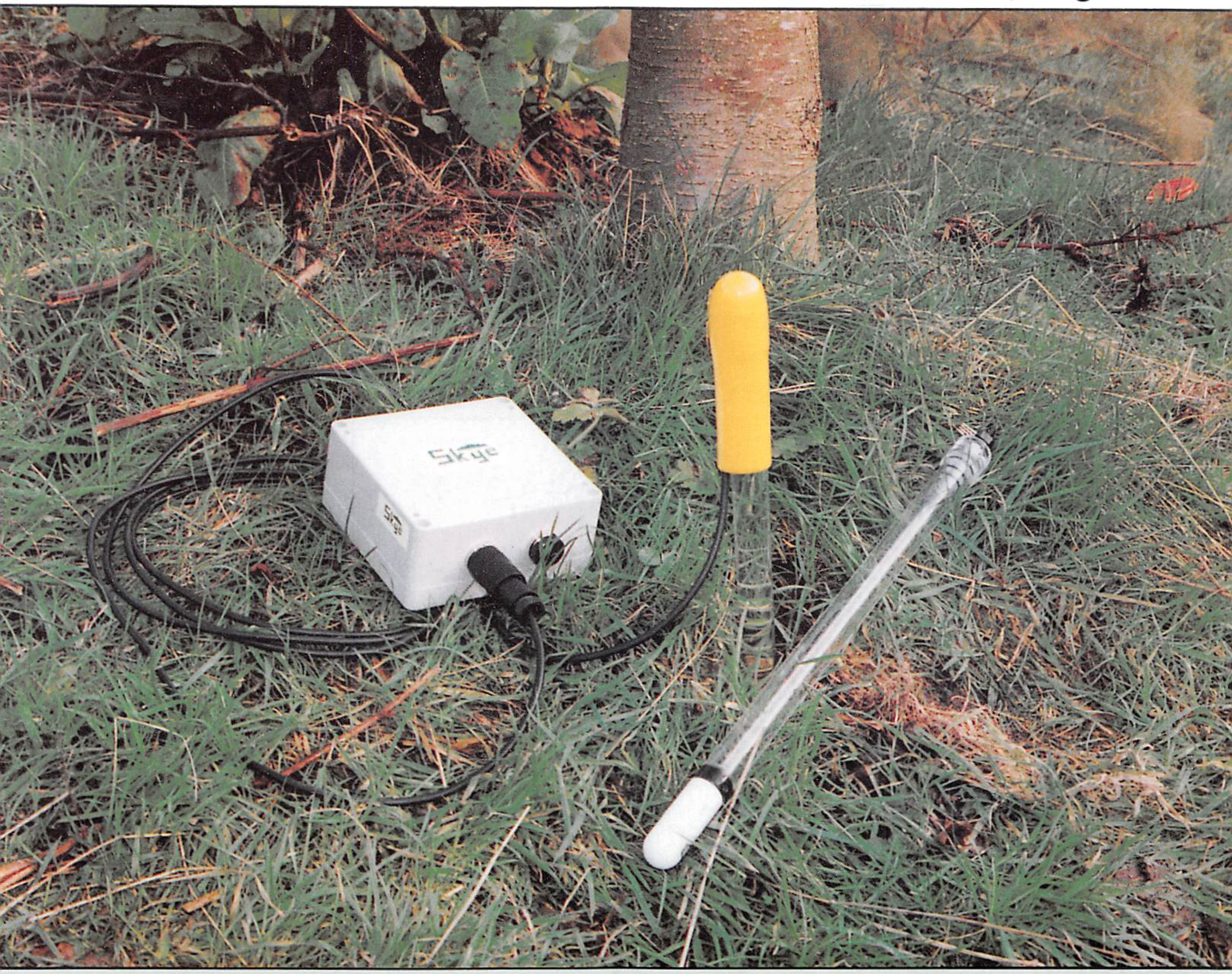
The Agricultural Engineer

Incorporating **Soil** and water

Volume 47 Number 1 Spring 1992

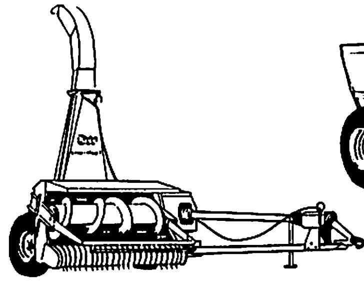


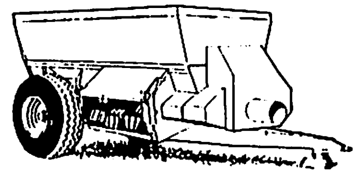
Environmental monitoring and controls

AE 47(1)

Kidd

Taarup-Kidd Farm Machinery Ltd.





AGRICULTURAL DESIGN ENGINEER

New Product Development is going to be even more important for companies in the 90,s - new products are essential for growth, profit and future investment.

At **Kidd Farm Machinery** over ten per cent of our people are actively involved in the design, development and testing of new products; we are now looking for a further **top rate design engineer** to join our team as a result of increased workload following our merger with the Danish Taarup Group of Companies.

You will be a **qualified creative design engineer** with good experience of:

- the agricultural equipment manufacturing industry, in the UK and mainland Europe.
- handling development projects from conceptual design, right through to the successful start up of production.
- working as part of a team within design, test and production engineering.
- production engineering techniques and of incorporating cost effective production methods into the product at the design stage.
- working with current British and European Standards, in particular BS 5304, BS 308.
- CAD systems and fully computerised engineering data base.

An excellent salary and large group benefits are available for the right person, plus the opportunity to work in a challenging environment with one of the leading British manufacturers.

For more information and an application form please write or telephone

Nick Paul, Engineering Manager, Taarup-Kidd Farm Machinery Ltd,
Roundway, Devizes, Wiltshire, SN10 2HP Tel: (0380) 722361 Fax: (0380) 729067

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Front cover: Environmental monitoring probes from Skye Instruments. *(See page 3).*

Regular Features

Journal and Proceedings

CONTENTS

COMMENT

Barry Shepperd

Having held the post of Honorary Editor of the *Agricultural Engineer* since early 1990 it is gratifying to have had far more compliments regarding changes to the Journal than we have received 'brick bats'. We have tried to make the Journal a more readable document whilst maintaining its technical integrity. I say 'we' because much of this has been achieved as a result of the editorial panel decisions, but most of all by Geoff Baldwin our Production Editor who's flair for layout and design has not gone unnoticed by the panel or indeed by the readership, as you will see from the letter on page 25. No doubt having made this statement I am inviting further criticism. However, we welcome comment and constructive criticism so please feel free to add your 'pennyworth'. Indeed, we would like very much to increase dialogue with and between our readership about both style and content, and about individual papers.

One item that has been especially welcomed in comments to me, has been the inclusion of information on changes in the law that affect our industry. We have Michael Darke, the editor of *Farm and Garden Machinery Law,* where the information can be obtained in far greater depth, to thank for allowing us to highlight items which we think will interest you.

In a further note on page 25 I give more details of editorial policy. Readers' comments and editorial contributions will be welcomed.

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Silsoe smell business! – offactometry service now available

Smells are a subjective business. However, the technology exists to produce objective measurements of odours – technology which is now available from Silsoe Research Institute and ADAS Mechanisation.

The odour measurement service now set up at Silsoe can be used to measure emissions from agriculture, from sewage works, and from industrial or food processes.

The basis of the new service is an offactometer, one of only two units in the country. Both units were originally located at IGAP, Hurley – now the Institute for Grassland & Environmental Research (IGER) – and the project team originally formed to investigate the control of odours involved Silsoe Research Institute, Silsoe College, ADAS and Hurley.

Research into machines and systems, and the processes of odour emission

In the early days, the commonest cause of complaint was about smells coming from slurry spreading. The Institute and the College were researching machines and systems for dealing with the origin of the problem, eg injectors, while Hurley was involved with means of odour measurement and sampling from spread slurry.

With the forthcoming closure of IGER at Hurley, one of the offactometers has now been transferred to Silsoe Research Institute, and the other to IGER at North Wyke.

Research at North Wyke will be into more fundamental means of odour control in livestock farming. The project will seek to understand the actual process of odour emission and to determine how it can be stopped at source, for example, by adding inhibitors to pig feeds.

Other projects will look at the use of biofilters, novel systems of pig keeping, odours from livestock housing, and slurry processing, in a mix of commercial and MAFF-sponsored work being carried out by the team at Silsoe Research Institute, within the Process Engineering Division, led by Roger Phillips, and by ADAS Mechanisation.

Services comply with European guidelines

The twinned offactometry services being offered by Silsoe Research Institute and IGER are believed to be the only UK odour measurement facilities which comply with European guidelines that specify the type of equipment and procedures which should be used.

Details from Robert Sneath, Process Engineering Division, Silsoe Research Institute, or Colin Clarkson, ADAS Mechanisation, Silsoe.

Offactometers in action, using members of the public to assess colour concentration, intensity, and offensiveness. The system is fully computer controlled, and uses samples collected in special bags.

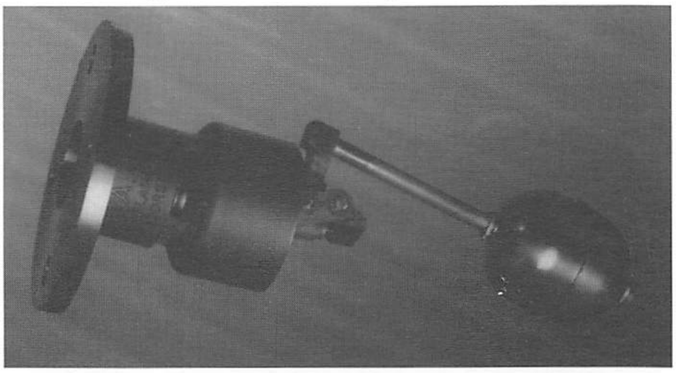
Racal Powerplus gas/vapour respirator

Described as the world's smallest and lightest power-assisted gas/vapour respirator, the new Powerplus from Racal Safety Ltd has a filter unit attached directly to the facemask and features a 'breath responsive' system, supplying filtered air to the wearer only when required.

This fully-approved respirator offers protection against organic vapours, aerosols and dusts making it suitable for most procedures involving pesticides and fumigants. Powerplus can replace conventional gas mask and canister systems by giving the same level of protection without the breathing resistance allowing the wearer to remain comfortable longer and work more effectively.

Racal Safety Ltd, Beresford Avenue, Wembley HA0 1QJ. Tel: 081 952 5566.

Safe filling of fuel tanks up to the top



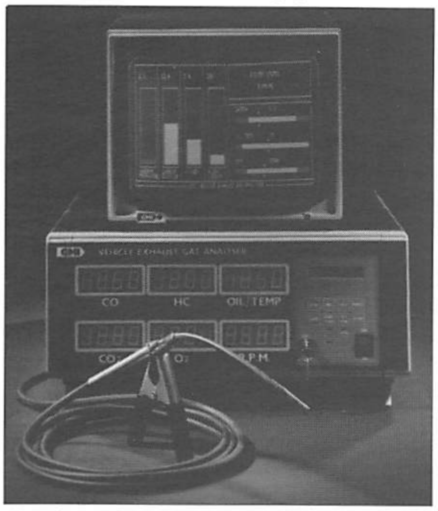
A stainless steel fill control valve which ensures reliable shut off at a predetermined tank level has been added to the range of fluid handling equipment manufactured by Alan Cobham Engineering Ltd (Blandford Forum, Dorset DT11 7BJ. Tel: 0258 451441).

A special feature of the valve is that it allows the tank to be filled up to capacity, increasing utilisation, therefore reducing the number of deliveries. It can also be used as an automatic 'top up' valve for buffer tanks in process applications.

The valve uses a float operated servo design which does not require external power or electrics to give reliable operation. The float mechanism is used to seal off the servo chamber, which has a greater cross sectional area than the valve inlet. As the inlet pressure builds up within the servo chamber, via a hole in the valve head, the servo effect closes the valve head against the liquid flow.

Alan Cobham offers versions for top, bottom or side mounted applications with shut off level to suit customer requirements. The valves are suitable for flow rates up to 80 gal/min and pump stall pressures of 50 psi.

GMI vehicle exhaust gas analyser, VEGA, gains OIML Class II approval



Gas detection and monitoring are increasingly vital to the world's energy-related industries and in working commercial environments.

GMI Gas Measurement Instruments Ltd, Renfrew (Tel: 041 812 3211), design and manufacture portable and personal monitors for flammable and toxic gas or oxygen measurement, and permanently installed alarm systems and analysers for a vast range of environments. Stringent quality control is carried out and most products are certified to BASEEFA standards.

From this strong, technical base GMI have introduced the VEGA range designed for the new MoT regulations. The company points out that this is the first UK approved Class II analyser from SIRA.

Gas chromatograph now for air sampling

The capabilities of a gas chromatograph can be greatly enhanced by adding the new automatic thermal desorber, the Aerotrap 6016 from Ai Cambridge Ltd (Tel: 0223 834420) to a Tekmar 2000/2016 purge and trap autosampler. The chromatograph can then deal with soil and water samples using the 2016 as well as air samples using the 6016.

Two versions of the new thermal desorbers, produced by Tekmar, will be available in the UK from Ai Cambridge Ltd. The Aerotrap 6016 can accommodate up to 16 individual air trap tubes. Either 1/4 or 1/2 inch diameter traps are catered for using easily interchange-able heater banks.

A further 16 position autosampler, the Aerotrap 6032, may be added to increase the sampling capability to 32 tubes.

The Aerotrap has been designed to minimise any cross contamination or sampling errors. An 'autobake' facility enables all lines connected to the desorbing tubes to be baked out, ensuring a clean system. The trap tubes themselves can be cleaned by heating to 350°C.

Quantitative results are enhanced by prepurging the trap before heating to remove oxygen and water vapour. Traps are then preheated to allow the trap temperature to equilibrate before desorbing. The dedicated Autosampler system for analysis of air samples prevents carryover and cleaning or replacing of lines.

The Aerotrap system further extends the Ai Cambridge range of complete integrated chromatograph packages.

Intelligent sensors for environmental monitoring

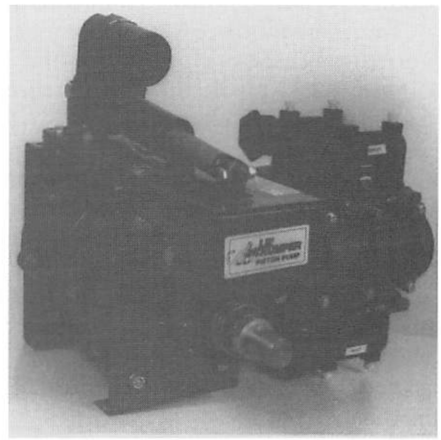
Skye Instruments Ltd, Llandrindod Wells (Tel: 0597 824811) have recently introduced an integrated sensor and data logger to their range of environmental monitoring probes. These units are self contained in a weatherproof housing sealed to IP65, powered only by a small battery for unattended logging up to 6 months. Measurements of air and soil temperature, soil moisture, relative humidity, light, sun radiation and rainfall can be logged with these stand alone devices in single or multichannel format. Installation is very simple, especially with integral sensor models as there are no trailing wires or cable length problems.

Data can be logged at user selected intervals from 30 seconds to 2 hours with over 5,300 records per file. This data is easily accessible via a PC either on site or back at the workplace and is compatible with most commercial spreadsheets. The intelligent sensors can also be synchronised making environmental monitoring at different sites possible.

Dosing pump offered by FLO-TAG

Highly accurate control of spray chemical application without need for electronics, is the claim for the D.P.A. pump the 'Lil-Thumper' introduced to the UK by FLO-TAG of Rugby (Tel: 0788 535981).

The pumps, of stainless steel, together with patented, synthetic corrosion resistant materials are offered either single piston (up to 75 l/min) or twin piston (up to 150 l/min). Stroke length is set by scale and spanner, to give stepless selection of output per hectare, which once set, will remain constant, regardless of changes to: product type, product density, or pressure. Prices start from £1460 + VAT.



The Countryside Union

TGWU picks up the banner for environmental protection

With the former UAAW now firmly inside the all embracing TGWU, moves are being made to extend the scope and influence of the former Agricultural and Allied Workers.

As from December last year the TGWU has added 'Rural' to the name of its agricultural workers section – now aimed to cover the interests of Rural, Agricultural and Allied Workers.

Announcing the new concept, TGWU General Secretary, Bill Morris, declared: "No other countryside organisation has a more detailed knowledge of the problems of rural people, or a longer history of dealing with those problems, or a more comprehensive rural network".

The launch programme for the new-styled section declares that the union will 'campaign for vital rural community issues, and for environmental protection'. Green issues identified in the programme include:–

– protection of landscape features and a balanced ecology;
– diversified farm production and multi-objective land use;
– an increase of diverse, sustainable forestry which combines ecological, amenity and economic requirements;
– integrated planning at all levels for conservation, recreation and employment.

Ag Tech apprentice scheme introduced by John Deere

A major new training scheme for the agricultural machinery industry has been launched by John Deere Limited, in conjunction with Brooksby College, with the approval of City & Guilds of London Institute.

The John Deere Ag Tech apprentice training programme has been developed to assist dealers and their service departments in the recruitment and training of suitably skilled technicians. It is based on similar schemes operating in the automotive trade, and is a first for the agricultural machinery industry.

Recognised as National Vocational Qualification

Essentially Ag Tech is a four-year block release scheme leading to the new City & Guilds 402 Agricultural Mechanics Certificate, which is being introduced this year.

The standard three-year apprenticeship will cover all the normal engineering principles and systems, and include regular sessions at the John Deere Training Centre in Bingham. This is close to Brooksby College, which is near Melton Mowbray in Leicestershire.

During the additional fourth year, the trainee works at the sponsoring John Deere dealership, and attends at least three service schools at the John Deere Training Centre. Successful students then qualify for the John Deere Ag Tech Diploma.

Because the new scheme is accepted by City & Guilds, and is recognised as a National Vocational Qualification (NVQ), it will not cost the dealer or student any more than if he or she attended their local college block release agricultural mechanics course.

The first intake of students, who need to be aged 16 or over, is planned for September 1992. Brochures outlining the scheme are available from Brooksby College, area careers officers, John Deere Ltd and John Deere dealers nationwide.

Surveying for ground water wells in Nigeria

Geraghty and Miller Inc of Denver CO 80202, USA report on a successful project to locate sources of potable water in Nigeria and other African countries in the fight against Guinea worm infection.

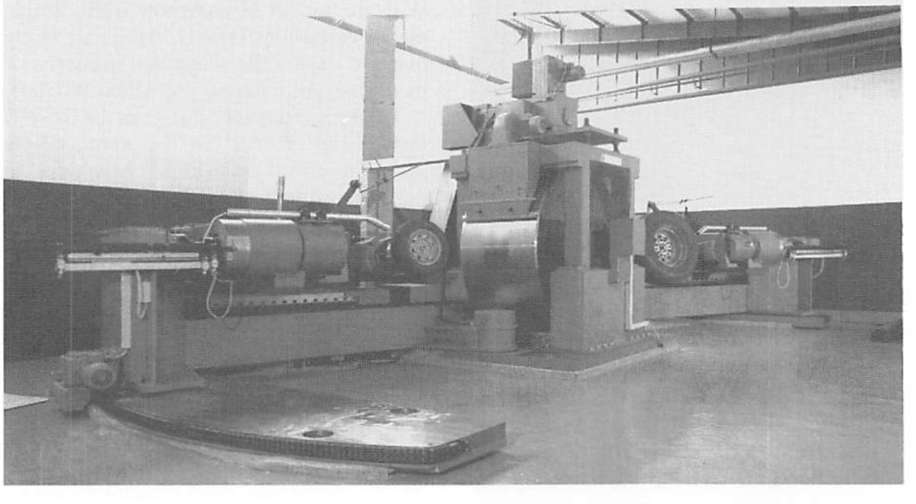
Guinea worm *(dracunuliasis)* is common in stagnant ponds in Nigeria and is ingested when a person drinks from these ponds. To combat the infection and break the cycle of disease a United Nations Development Programme has been established with the goal of 'setting up systems (that local governments can operate) integrating water, hygiene, education and sanitation'.

Consultant to the Programme has been Dr W E Wightman, a Principal Geophysicist at Geraghty and Miller, and the procedure to find sources of ground water has been firstly to use electrical traversing to locate promising areas, followed by electrical depth soundings to determine the depth and amount of water. During his two trips to Nigeria, one during July 1990 and the other in January 1991, Dr Wightman has undertaken the training of a group of Nigerian hydrologists and geologists and has visited several villages with the group. The trainees have since conducted surveys at numerous villages, selecting sites for ground water wells. A very high percentage of the wells at these sites have successfully found water.

Dr Wightman's firm, Geraghty & Miller Inc, has specialised in ground water technology since its founding in 1957 and has provided ground water services worldwide in all types of geological environments. However, this project is a singular example of how science is integrated with and is integral to daily lifestyle.

Geraghty & Miller Inc is a full-service environmental firm offering a wide range of scientific, engineering, and management services. The firm specialises in the development, management, and protection of ground water resources, and the assessment and correction of ground water contamination problems. For more information contact: W Edward Wightman, Geraghty & Miller Inc, 1099 18th Street, Suite 2100, Denver, CO 80202, USA, Tel: 303/294-1200.

Tough testing for wheels and tyres



Alphadelta Ltd, the UK subsidiary of Fabbrica Assali Dischi (FAD), manufacturers of wheel equipment, announce that the world's toughest and most modern testing equipment has been installed at the manufacturing plant at Carpenedolo, Italy.

The new equipment, manufactured by Hasbach & Menschner GmbH, Germany, represents an investment of £400,000 by the company. The equipment comprises a two station rim testing machine for complete examination of wheels and tyres for agricultural trailers, fork lift trucks, etc. Wheels and a combination of wheels and tyres can be tested to destruction.

The method of testing is by rolling under defined wheel load at a pre-selected tyre pressure on a vertically installed driven road wheel. Test tyres are fitted on to test rims manufactured by FAD.

The unit has two stations, one either side of the central road wheel with mechanical layouts which provide for sweeping slip angle variation on tyres with pre-set camber. During testing the parameters, speed, tyre load, slip angle and tyre internal pressure can be varied, measured and recorded to test programme demands.

The whole unit is operated from a control desk with all the relevant test information displayed digitally on a standard VDU and with paper print out. The whole testing facility is controlled by a Siemens S5115U control system which is equipped to interface to an IBM PC80 computer system. This provides for automated testing operation with automated data acquisition and documentation.

The units are capable of testing tyre diameters up to 2000 mm with a slip angle variation of + or − 10° and a camber variation of −5 to +20°, a maximum tyre load of 120 kN with a driving speed up to 150 km/h is possible. Maximum air pressure is 12 bar and the testing station load is up to 7000 kg.

The installation of the new testing equipment is just part of an ongoing drive to ensure all FAD products from Alphadelta meet the quality standards of countries worldwide for continued performance and to meet the most exacting demands of OEM's, ensuring their requirements are met every time, without failure.

Sprayer cab meets latest Forced Air Filtration standards

Europe's first safety cab for forward control sprayers has been launched by Sands Agricultural Machinery of Stalham, Norfolk (Tel: 0507 313798).

The new cab, which is to be fitted to all SAM forward control sprayers, is engineered to OEDC Roll-Over Protection Standard (ROPS) and has been tested to the maximum weight of the largest Sands sprayer by Silsoe Research Institute.

Other improvements mean it is currently the only cab to meet the latest Forced Air Filtration Standards. The optional SAM air conditioning unit has also been improved. It no longer uses environmentally unfriendly CFCs and it has a bigger condenser for greater output.

The new cab has been introduced with the export market in mind and in the belief that specialist self-propelled vehicles such as sprayers, combine harvesters and forage harvesters cannot expect to remain immune from safety legislation.

Furthermore, says Sands, an increasing number of owners are exploiting the demount potential of forward control sprayers and if these machines are used for other purposes, such as drilling and cultivation work, a safety cab is required.

3M new organic vapour/particulate respirator

The 4251 Organic Vapour/Particulate Respirator incorporates numerous features to enhance performance and comfort. Believed to be unique, the facepiece shape of the 4251 respirator allows good peripheral vision and ensures that the respirator can be worn comfortably with other protective equipment such as spectacles and ear-muffs. A 'parabolic' exhalation valve design dramatically reduces heat build-up inside the respirator.

The special non-allergenic facepiece material has been selected to reduce weight and skin irritation. Its 4-point strap and multi-size harness provide a well-balanced fit for different head shapes and sizes.

The respirator is easy to care for. Carbon filters eliminate the need for granule containers and prevent sorbent particles from escaping. The respirator is simply discarded when the filters are exhausted. The 3M's 4251 respirator has been independently tested and approved as meeting the requirements of the new European respirator standard.

3M Health and Environmental Safety Group, 47 Aylesbury Road, Thame OX9 3PG. Tel: 0800 212490.

Rekord Sales (GB) Ltd – expands into industrial handling and storage

Rekord Sales (GB) Ltd is a name generally associated with agriculture as the company has been supplying grain conditioning and handling plant to farmers since its inception in 1956. However, some 18 months ago, Rekord took over UK distribution for the Swedish Company Akron (as well as taking on board the Akron specialist advisory and planning personnel), and as a result this has considerably broadened its marketing operation, which now extends to all sectors of industrial bulk handling and storage.

Rekord's product base now includes Westeel round and hopper bottom bins, Shivvers computerised high temperature, low cost bin drying systems, Akron square bins, Jema conveyors, cleaning and weighing equipment, Petkus grain and seed cleaning equipment, in fact, just about everything connected with drying, cleaning and handling – including dust control.

The company feels it is now in a strong and competitive position to offer benefits to medium sized companies or, where very large projects are concerned, it is happy to offer its services on a sub-contractual basis to installers larger than itself.

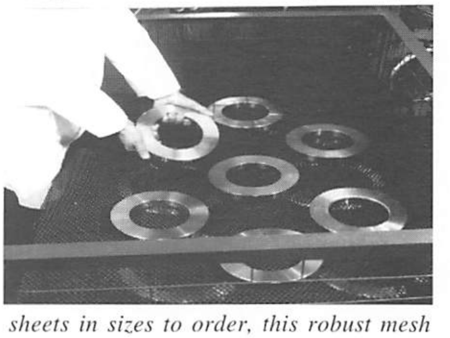
Further details: Rekord Sales (GB) Ltd, Manor Road, Mancetter, Atherstone, Warks. CV9 1RJ. Tel: 0827 712424. Fax: 0827 715133.

Protection in storage and handling

Abbott's Packaging (New Southgate, London N11 1HL. Tel: 081 368 0886) has added to its established range of protective storage and packaging materials the Netlon 'Stillage Separator', a flexible, heavy duty, polyethylene mesh, especially designed to separate vulnerable items within metal stillages and to prevent damaging contact between machined surfaces.

The Netlon Stillage Separator is oil and chemical resistant and its open mesh structure allows rapid drainage of cutting oils and swarf, resulting in cleaner, uncontaminated components.

Supplied in standard roll form or flat sheets in sizes to order, this robust mesh can be reused time and again, enabling cost effective protection without the disposal problems associated with cardboard products.



Irrigation surveys by ADAS

With a further year of irrigation survey data to guide them, ADAS specialists can now indicate that somewhere between 200 and 240 million cubic metres of water could be needed for spray irrigation in England and Wales in a dry year. Supplies do not match this and peak demand for dry years will almost certainly have to be met from stored supplies.

Chris Stansfield here reports on the 1990 survey and its findings and implications.

Sir Nigel Strutt said in the foreword to his 1980 report Water for Agriculture: Future Needs – "The farming economy has changed a great deal in the last 20 years and we can no longer afford the penalty of a bad year, if for no other reason than that fixed costs are too high and likely to remain so".

The past three very dry summers have brought this painful message home to those farmers and growers who rely on irrigation to keep their business alive.

The National Rivers Authority (NRA) restrictions – in the Midlands, South, South East and, particularly, East Anglia – have placed an additional burden on those who grow crops on soils that need water to produce economic yields.

What effect the shortage of water has had on the individual business is not known, nor is the impact on imports or rural employment. All we can say with confidence is that if these highly skilled farmers and growers cannot supply the supermarkets with the quality and quantity that their customers demand then the supermarkets will have no hesitation in looking abroad for their supplies.

Table 1. Actual areas of crops irrigated and volume of water supplied.

	Crop area, ha				*Water volume ('000 metres³)*			
	1982	*1984*	*1987*	*1990*	*1982*	*1984*	*1987*	*1990*
Potatoes, harvested by 31 July	8,050	7,720	5,360	8,510	4,680	4,920	2,350	6,770
harvested after 31 July	22,810	34,610	29,520	43,490	15,280	32,730	14,700	51,170
Sugar beet	15,770	25,500	10,110	27,710	8,260	17,370	3,430	20,320
Orchard fruit	3,100	3,250	1,330	3,320	2,180	2,430	550	2,930
Small fruit	3,610	3,560	2,230	3,470	1,890	2,660	970	3,180
Vegetables for human consumption	14,810	17,460	11,040	25,250	6,830	11,390	4,640	18,450
Grass	16,440	18,940	6,970	15,970	10,030	13,550	3,550	13,100
Cereals	14,800	24,700	7,510	28,100	5,040	8,300	2,160	11,830
Other crops grown in the open	4,100	4,890	2,440	8,650	1,020	4,030	1,270	6,040
TOTALS	103,490	140,600	76,520	164,460	55,210	97,370	33,620	133,790

Totals may not exactly agree with the sum of their components due to rounding.
Reference to other published statistics suggests that the acreage of the crops grown each year remains broadly constant over the period concerned. The variations from survey to survey in the area irrigated and in the volume of water used thus reflect the nature of the season and do not indicate any sudden change in acreage of a particular crop.

Spray irrigation and water usage

In 1989, which is the last year for which figures are available, the total quantity of water abstracted per day was 33.3 million cubic metres. Of this, piped water supplies accounted for 54%, power generation 37%, while spray irrigation accounted for less than 2%.

So why have farmers suffered so badly?

Basically, it is because spray irrigation uses a lot of water in a short period of time when usable rainfall is lowest and other uses are also at their maximum. There are also marked variations in the use of water for spray irrigation from season to season which makes planning difficult. In addition virtually all of the water is lost, the water being absorbed by the crop and lost in transpiration so that little is recyclable.

This scenario provides a powerful incentive to know how much water is used for spray irrigation, where it comes from, what it is used for and what on. The information is needed by the NRA so that they can include it in their planning process to provide sufficient water for all future uses.

It is for this reason that the Ministry of Agriculture, Fisheries and Food implemented the present series of Irrigation Surveys which started in 1982. These surveys are the only ones of their type to find out from the users what water is actually applied. The Surveys are organised and carried out by the Agricultural Census Branch of the Government Statistical Service with technical assistance from ADAS and the NRA.

C B Stansfield is ADAS Senior Soil and Water Engineer, Nobel House, London.

Survey maintains individual confidentiality – but aggregated data give valuable information for planning

The survey was based on a trigger question inserted in the 1990 June Agricultural Census which asks: "Do you irrigate outdoor crops?" The 5700 farmers and growers who answered "yes" received a more detailed questionnaire in February 1991 which asked questions on what areas of crops were irrigated, how much water was applied, the source of water, type of equipment used and areas equipped for trickle irrigation and frost protection. One important question was: "What area would you irrigate and how much water would you use in a dry year?"

We know that farmers do not like filling in forms so the layout is made easy to follow with clear questions so that the end result is meaningful data. As with all similar surveys all information is aggregated and we guarantee that no data on individual holdings can be identified.

The information collected is used at a strategic level to improve the water resource planning process. The NRA who are responsible for managing the nations water resource use this data to ensure that the farmers and growers requirements are properly represented. The data is also used in scientific studies, for European Community purposes and by manufacturers and suppliers.

Big increase in irrigation and water requirement in drought years

Table 1 shows the actual areas of crops that were irrigated and the volume of water that was applied in England and Wales in the 1990 irrigation season along with the comparable figures for earlier survey years.

The area irrigated reflects the areas that were irrigated and not the actual area grown. Drought years such as 1984 and 1990 have higher figures which would be expected. In 1990 the area irrigated had risen by 17% compared with 1984. It is interesting to note that whereas the area of potatoes irrigated rose by 23% the area of vegetables irrigated increased by 45%. This reflects the intense pressure that this market sector is under to produce reliable yields of consistent quality for the supermarket trade.

The figures for water volume confirm that 37% more water was applied in 1990 than in 1984. More water was applied per unit area. Once again it was the vegetable crops which showed the largest increase.

Table 2. Sources of water and volume used.

Water source	*Water volume ('000 m^3)* 1982 *Volume*	*%*	1984 *Volume*	*%*	1987 *Volume*	*%*	1990 *Volume*	*%*
River, stream or other watercourse	27,520	50	47,840	49	16,000	48	62,330	47
Spring rising on holding	2,580	5	4,370	4	1,580	5	5,360	4
Well	2,560	5	3,210	3	1,130	3	3,230	2
Deep boreholes	11,540	21	24,840	26	9,090	27	41,950	31
Pond or lake	5,800	11	8,470	9	2,870	9	9,570	7
Gravel or clay working	1,070	1	1,260	1	380	1	2,170	2
Public supply (mains)	2,040	4	3,840	4	1,100	3	3,860	3
Other source	1,830	3	3,540	4	1,470	4	5,330	4
TOTALS	54,940		97,370		33,620		133,790	

Rivers, streams supply 50% of water

Table 2 shows where the water used comes from. Rivers and streams have always provided around half the water and this trend continues. What is perhaps surprising is the amount used from boreholes which has increased steadily over the years. This is most probably due to additional pumping from existing boreholes rather than the development of new sources.

The total capacity of storage facilities in 1990 was 37.08 million cubic metres as against 37.19 million cubic metres in 1987 compared with 33.46 million cubic metres in 1984 and 21.7 million cubic metres in 1982.

The number of earth and lined earth reservoirs continues to grow being 2580 in 1990 compared with 2420 in 1987 but still below the peak number in 1984 of 2700. Taken with the total storage capacity this would indicate that some larger reservoirs have been de-commissioned and more smaller ones constructed.

It is also possible that some former irrigation reservoirs are now used for other purposes such as angling.

Table 3. Equipment used – self propelled irrigators.

	No. of machines 1982	1984	1987	1990
Rain guns	2,720	4,210	4,530	5,270
Boom type	440	560	350	280
TOTAL	3,160	4,770	4,880	5,550

Steady growth in use of self-propelled rain guns

Farmers and growers are asked to indicate the type of self-propelled irrigators that they use and this is shown in Table 3.

This confirms the trend to increased use of the more flexible rain guns and a reduction of boom type machines. Table 4 summarises other aspects of equipment.

Irrigation in a dry year

This is always a problematical question because the results depend on the interpretation of a dry year which varies from person to person and on their perceptions at the time. The question is aimed at obtaining the best estimate of what farmers would want in a dry year in order to put an upper limit on water needed and area irrigated.

In 1990 this question confirmed that 202,600 hectares would be irrigated using 179 million cubic metres of water. This compares with the actual area irrigated of 164,460 hectares and volume of 133 million cubic metres even though 1990 was one of the driest years this century.

Table 4. Number of holdings using other types of equipment

	Number of holdings 1982	1984	1987	1990
Sprinklers and spray lines	6,550	4,070	2,890	3,020
Rain guns (not self-propelled and not for slurry)	700	580	370	400
Trickle equipment	890	640	490	600
Mini-sprinklers (orchards)	350	200	130	150
Other equipment (eg centre pivot, linear)			140	190

Studies by Bailey and Minhinick (1989) using computer simulation of cropping, soil and climatic data indicated that in the driest year 237 million cubic metres of water would be needed and 109 million cubic metres in the 5th driest year of 20. Both forecasts are made on the assumption that the irrigated area remains constant which in practice is unlikely to happen. It is also interesting to compare this with the total quantity of water licensed in 1988 of 200 million cubic metres.

Overall, 1990 was a remarkably dry summer. The drought started at the end of February and soil moisture deficits started to build in March. Rainfall continued well below normal through April and May, but June produced rainfall close to average over most of England and Wales. In July the dry weather resumed with typically 25-75% of normal rainfall, but closer to normal in northern counties.

Table 5 presents Potential Soil Moisture Deficit (PSMD) calculations for four locations within the main irrigation areas and compares them with the long term average. PSMD is the moisture deficit that the soil would achieve if it were able to transpire at the full potential rate – ie assuming the crop is not under moisture stress. As such it differs from Soil Moisture Deficit (SMD) which relates to deficits actually achieved.

Accordingly the PSMD gives an objective measure of the droughtiness of a season.

Benefits of irrigation

Although a major benefit is the increase in saleable yield other very important benefits are to improve the quality of saleable yield, continuity and reliability of supply and timeliness of harvest. Water is increasingly being used for crop establishment and to control or reduce disease. Last but by no means least is the need for irrigation to protect the business investment in plant and machinery and in suppliers' contracts.

Increasingly irrigators are aware of the costs of water in relation to their crops and water is being applied scientifically at the

Table 5. Weather conditions compared.

		Potential Soil Moisture Deficit (PSMD), mm					
		April	*May*	*June*	*July*	*Aug*	*Sept*
Cambridge	1977	35	85	110	205	140	185
	1982	135	180	170	200	275	275
	1984	55	45	55	150	175	110
	1987	40	80	50	60	55	75
	1990	70	160	220	325	425	465
	Average	20	60	105	140	155	160
Oxford	1977	20	60	35	140	75	115
	1982	45	95	115	175	215	215
	1984	70	70	140	240	295	265
	1987	35	70	60	120	165	190
	1990	65	160	190	295	370	395
	Average	15	40	80	115	120	110
Maidstone	1977	25	55	45	120	140	170
	1982	60	110	125	180	220	220
	1984	60	70	95	175	240	235
	1987	40	80	85	85	105	125
	1990	80	179	215	330	420	455
	Average	10	45	100	140	155	145
Nottingham	1977	30	70	50	135	120	140
	1982	50	120	50	130	90	95
	1984	65	80	115	210	215	185
	1987	35	90	65	90	95	110
	1990	85	170	170	255	315	350
	Average	15	45	90	130	130	125

critical growth stages rather than being wastefully applied when there is no economic benefit. Although we have no figures on the use of scheduling systems there is little doubt that these are a good investment for irrigators enabling them to prioritise water usage.

The 1990 survey is the fourteenth carried out by MAFF since 1955 and the last four have used the same basic layout so that results are directly comparable. The areas irrigated since 1955 are shown in Fig 1.

The future – more water storage needed

The current situation indicates that somewhere between 200-240 million cubic metres of water are needed for spray irrigation in the driest year. Supplies do not match this and it is expected that the NRA will take this into account in developing their water supply resource strategy.

The peak demand for dry years will almost certainly have to be from stored supplies and whether this is provided by the NRA or on individual farms will be an interesting debate. It can be argued that farmers and growers are experts in food production and the NRA at providing water and this scenario would lead to adequate supplies at cheapest cost.

Although water is in short supply there are many farmers and growers who need to use spray irrigation and they need a regular uninterrupted supply of water if they are going to be able to satisfy ever demanding customers and contribute to closing the trade gap.

The MAFF irrigation survey provides a sound basis for developing future water resource strategies.

Climatic change will also impact on irrigation requirements. Current estimates are for a 1.5°C rise in average temperature in the next 25 years and a similar rise in the following 25 year period. This will move the arable/grassland divide northwards, lead to the introduction of new crops such as navy and soya beans and with less summer rainfall in the south and east will increase the demand for irrigation.

Acknowledgements

To Alan Stephenson of the Agricultural Census Branch, Guildford and Ian Barrie of the ADAS Agrometeorology Unit, Wolverhampton.

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Survey data for England and Wales and on a Regional basis are available from Agricultural Census Branch, Government Buildings, Epsom Road, Guildford, Surrey GU1 2LD. Tel: (0483) 68121, ext 3577.

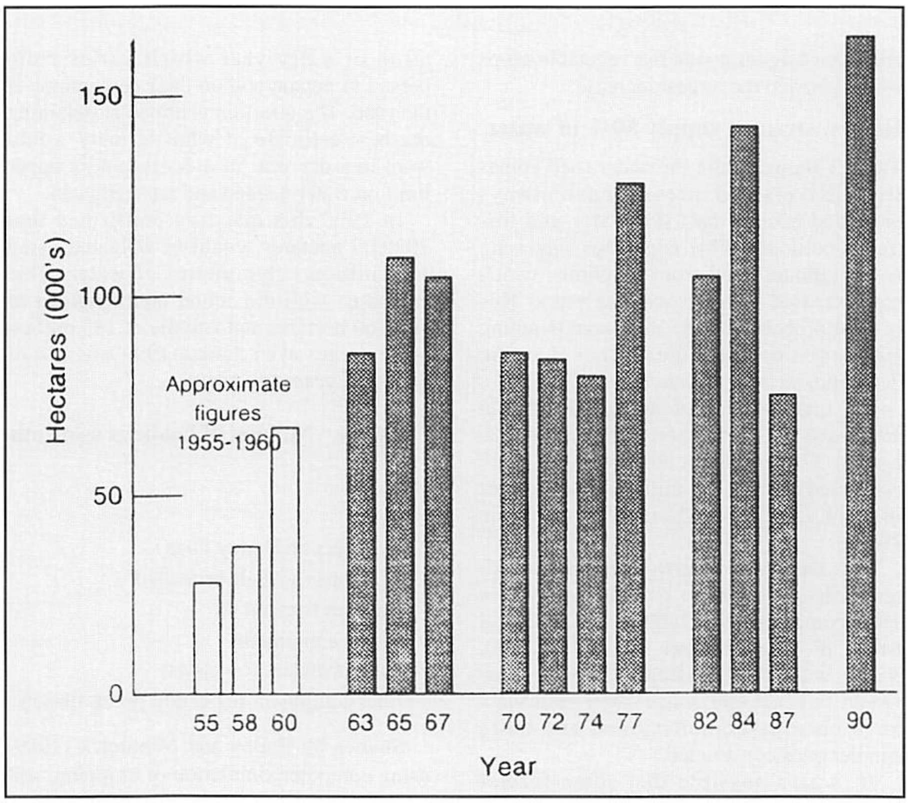
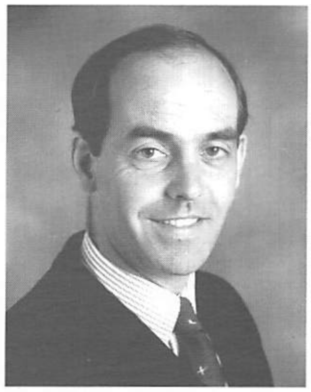


Fig 1. Area of irrigated land (surveys 1955 to 1990).

Direct injection systems on crop sprayers



Andrew Landers points out that the current COSHH (Control of Substances Hazardous to Health) regulations emphasise the need to limit or avoid exposure rather than just to protect against it. In spraying, the aim must be for less handling of chemicals and for greater precision in preparation and application. Direct injection systems now made possible by modern electronics are seen to be an important development.

Concern for the safe handling of pesticides has increased considerably in recent years and the introduction of legislation has helped protect the operator and reduce environmental pollution.

The Control of Substances Hazardous to Health Act (COSHH) enacted in October 1989, requires the exposure to hazardous substances to be either prevented or, where this is not reasonably practicable, to be adequately controlled. Regulation 7(2) requires that prevention or control is secured by measures other than the provision of personal protective equipment.

Control must, so far as is reasonably practicable, be by engineering control methods. Increased awareness by the general public about environmental pollution has also increased the need for farmers and equipment manufacturers to examine their methods of pesticide usage. Furthermore, with the margins for farmers and growers decreasing, there is a need for accuracy, timeliness and safety if optimum use of pesticides is to be achieved.

The direct injection sprayer

With sprayers, a major area for development lies in reducing the handling of chemicals and of the chemical containers. Recent advances in electronics have resulted in the development of dosing systems to inject pesticide into the sprayer.

A conventional crop sprayer is fitted with an injection system comprising one to four pumps which will dispense pesticide at a known rate into the water stream in the sprayer pipeline. The main tank of the sprayer holds clean water only. The pesticide is mixed with the water, either in a manifold or at the main water pump, and the solution of pesticide and water flows to the booms.

A controller adjusts the pesticide pump output according to changes in operating parameters, eg in forward speed, boom sections switched on/off, etc. In an ideal world pesticide would be removed from the original manufacturer's container. Fig 1 shows the basic concept of injection.

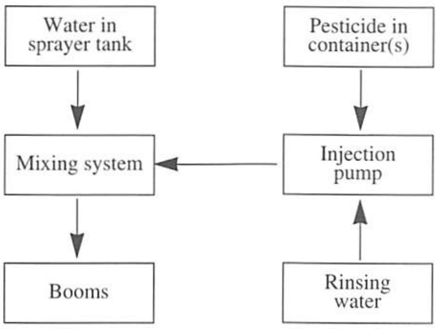


Fig 1. The basic concept of direct injection.

Commercially available direct injection systems

There are two systems currently available in the UK, the AgriFutura Dose 2000 and the Mid-West Technology CCI-2000.

– The AgriFutura Dose 2000

This system has been developed in Sweden by AgriFutura AB over the last five years and evaluation trials have been carried out Cirencester for the past 18 months. The system is a kit which can be fitted to any conventional field sprayer, see Fig 2.

The 30 litre containers are filled with pesticide in the chemical store using a filling station. The filling station allows the operator to remove pesticide from the manufacturer's original, small containers into the larger container. It is important that container size matches the ratio of pesticide to water application to avoid running out of pesticide before the water tank is empty. The containers are fitted to the side of the sprayer.

The pesticide is withdrawn from the container by means of a probe connected via a pipe to a dosing pump. This comprises a ceramic piston operating in a stainless steel cylinder; the piston stroke length is altered by a stepper motor and gearbox. Power input is via the tractor power take off. Any changes in operating parameters result in the stepper motor altering the stroke length, thereby increasing or decreasing the amount of pesticide injected.

The pesticide is delivered by pipes to a mixing chamber, situated between the water pressure regulating valve and the boom selection valves, where it joins with clean

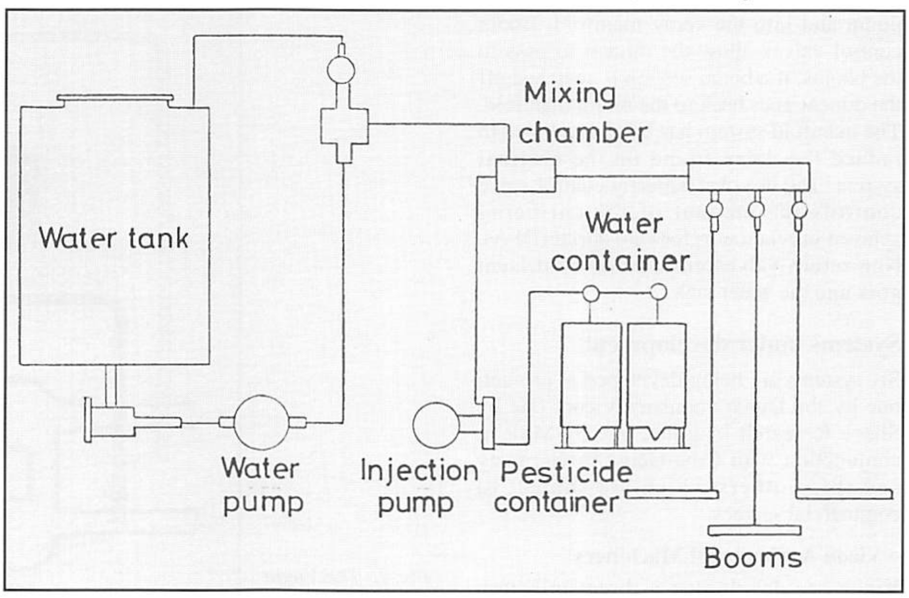


Fig 2. The AgriFutura Dose 2000.

Paper given at the Scottish and Yorkshire Branches of the Institution in November 1991.

A Landers is Senior Lecturer in Agricultural Mechanisation at the Royal Agricultural College, Cirencester.

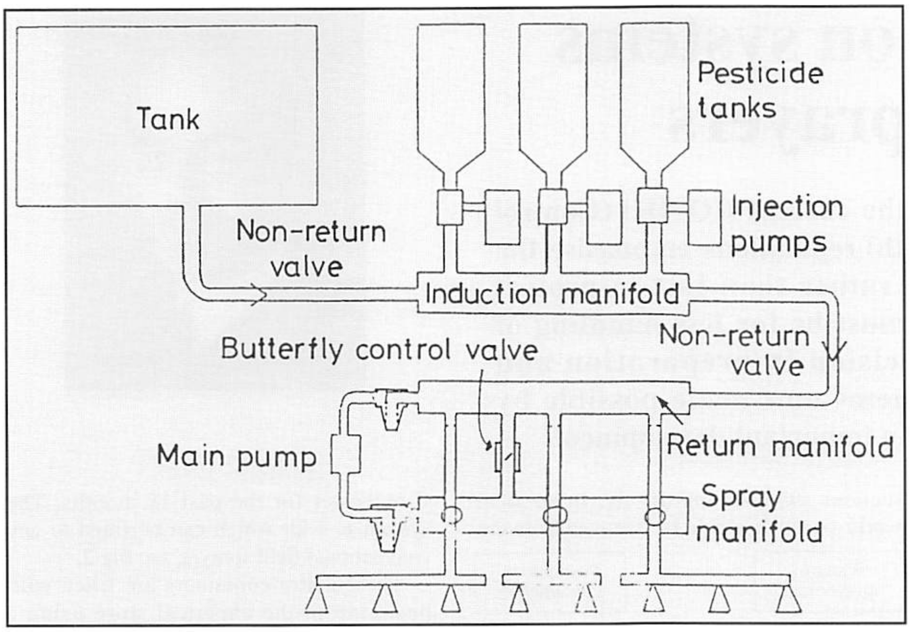


Fig 3. The Mid-West Technology CCI-2000.

water from the sprayer tank. The diluent then passes out to the boom.

– The Mid-West Technology CCI-2000

The Mid-West Technology CCI-2000 was developed in the USA in the mid 1980s and has been imported and modified by Handbury Machinery Services for the past three years.

The system (see Fig 3) comprises individual cone bottom pesticide tanks as up to three pesticides may be applied. The tanks are connected to peristaltic tube pumps which meter the pesticide into the induction manifold where it joins with clean water from the sprayer water tank. The pumps are driven by 12 volt variable speed electric motors. By varying the motor speed and tube size, the pumps can inject pesticide within a wide range of application rates.

The diluent passes through the stainless steel return manifold, through the sprayer pump and into the spray manifold. Boom control valves allow the diluent to pass to the booms, if a boom section is switched off the diluent goes back to the return manifold. The manifold system has been developed to reduce the delay found on the original system. The use of a butterfly control valve controls the amount of diluent being sprayed in relation to forward speed (DPA). Non-return valves ensure that no diluent goes into the water tank.

Systems under development

Six systems are being developed at present, one by the Dutch company Vicon, one by Silsoe Research Institute, one by MSR in conjunction with Ciba-Geigy in Germany and three others which are subject to commercial secrecy.

– Vicon Agricultural Machinery

Vicon are developing a direct injection closed system sprayer in Holland and England. Fig 4 shows the layout of the system.

The injection system comprises a dual tube peristaltic pump. This pump has both a large bore and small bore tube, which allows the operator to select a wide range of application rates. The dual tube peristaltic pump is driven by a variable speed electric motor. The pesticide is removed from the container by means of a probe via the pump to the inlet side of the main sprayer water pump. The quantity of pesticide being injected can be altered by varying the speed of the electric motor.

The pesticide joins the flow of water and is thoroughly mixed as it passes through the water pump and out to the sprayer boom. The water pump is an axial piston pump (swashplate pump) and so the output can be altered according to requirements; eg change in speed, boom section being shut off, etc. The change in output is effected by moving the swashplate via an electric motor, thereby adjusting the stroke of the pistons.

The dual tube peristaltic pump and main water pump can be regulated together. This allows for a change in pump output whilst maintaining a constant concentration of pesticide in the water.

– Silsoe Research Institute – application rate control system

A novel direct injection closed system sprayer is being developed by Silsoe Research Institute at Wrest Park, Silsoe. A technique has been developed, where the pesticide is removed from the manufacturer's original container and transferred to a cylinder. A probe is placed in the original container and suction is created by a piston moving within the cylinder and thereby withdrawing the pesticide. The piston is moved within thecylinder by means of water being withdrawn from one side of the piston. A venturi, situated in the sprayer return line between the water pump and the water tank, creates the suction. This action is similar to that of a hypodermic syringe (see Fig 5).

The piston direction can be reversed

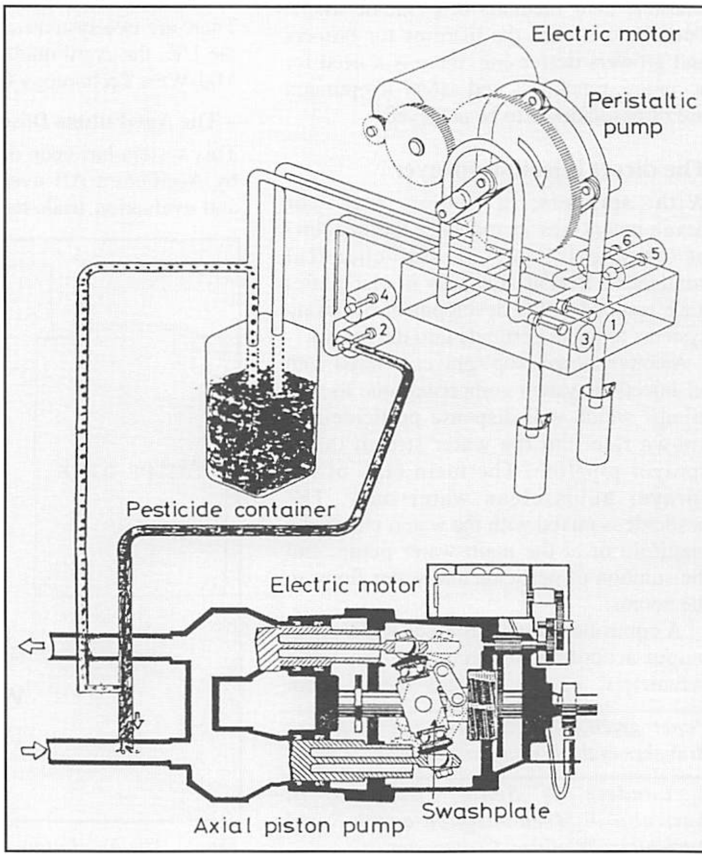


Fig 4. The Vicon Injection System.

within the cylinder, thus pushing out the pesticide into a mixing chamber situated in the sprayer water line between the water pump and the boom. The piston is pushed by means of a metering pump which withdraws water from the main water line. The pressure sensors are used to monitor the difference in pressure at the metering pump. The controller calculates the flow rate, due to pressure differences either side of the pump, pump speed and forward speed. The flow rate of water into the cylinder is equal to the flow rate of pesticide from it.

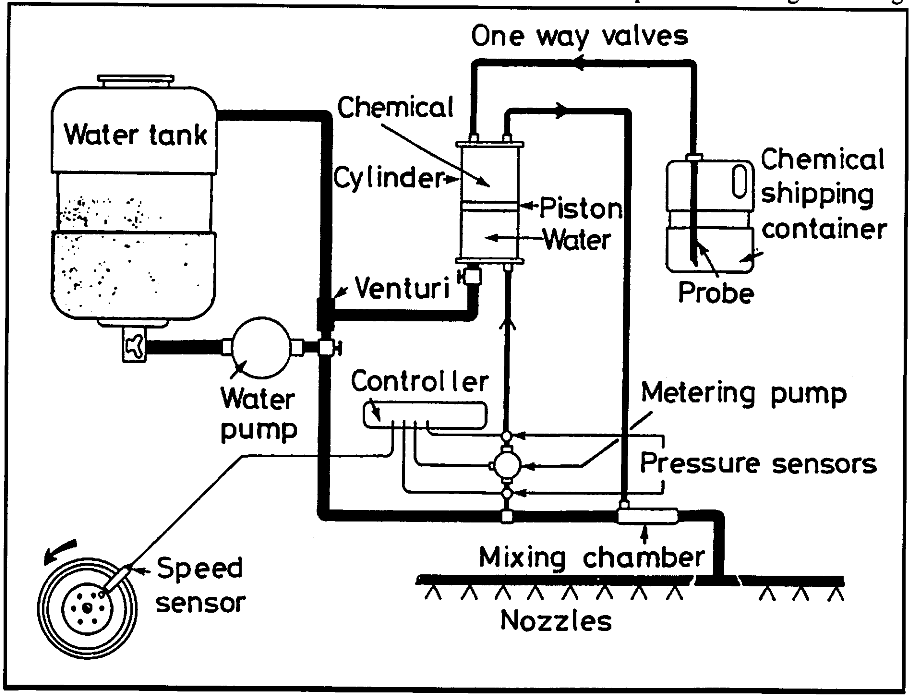


Fig 5. The Direct Injection Closed System developed by Silsoe Research Institute.

– MSR Ciba-Geigy Agroinject

This injection system comprises a single dosing pump which is water driven, being fitted into the water flow pipe.

A suction probe is fitted into each pesticide container (up to four containers can be used) and pesticide is withdrawn into the single dosing pump (Fig 6). Up to four products can be injected simultaneously. A separate mixing chamber ensures thorough mixing of the water and pesticides. The application rate is set before operation, although individual containers may be switched on or off by means of solenoid valves. An in-cab controller monitors and controls the injection system.

Advantages of direct injection sprayers

Direct injection systems have several environmental, safety and financial benefits over conventional spray equipment.

Benefits to the Environment

- Only clean water is used in the main sprayer tank so there is no danger of pesticide carryover to non-cropped areas or the following crop to be sprayed.
- Water can be withdrawn from a natural water course without fear of suck-back of pesticide.
- There is no risk of spillage of concentrated product during mixing operations at the headland.
- Ease of spot treatment precludes the need for blanket treatment.
- Dose rates can be adjusted on the move to accommodate different levels of infestation, soil types and headlands, which prevents over-application of chemicals.

Benefits to the Operator

- The operator is not exposed to neat chemicals, the parallel development of closed transfer systems will lead to closed injection systems.
- The sprayer is easy to flush and the Distance Remaining feature allows rinsing before leaving the field.
- Nozzle throughput can be checked using clean water.
- The injection system is easily fitted to conventional sprayers.
- Simple controls allow the operator to change dose rates quickly and accurately.
- A simple calibration process allow use of all types of pesticide, from water soluble to wettable powders.

Benefits to the Farmer

- Better use of labour as the operator spends less time calculating, mixing and cleaning.
- Less pesticide wastage as left over chemical can be returned to the store.
- Accurate application by sophisticated electronic metering and precisely calibrated pumps allows cost-effective pesticide usage.
- Thorough mixing of pesticide prevents scorching.
- Reduction of input costs where effective spot treatment can be employed.

Programme of Research

A prototype injection sprayer – the Dose 2000, from the Swedish company AgriFutura AB – underwent evaluation trials at the Royal Agricultural College, Cirencester. Laboratory studies using potassium permanganate, investigated the mixing effectiveness, response times, and accuracy due to changes in operating parameters.

Results showed that pesticide concentration remained consistent, over a period of time when the pump injected pesticide at a constant rate. This was supported by field trial evidence on weed and disease control.

The pump output was linear at varying dose levels when using water, although the viscosity of certain pesticides at particular temperatures may require the pump to be calibrated specifically for them. The pump responded quickly to changes in forward speed and dose level adjustments.

Field trials were carried out using

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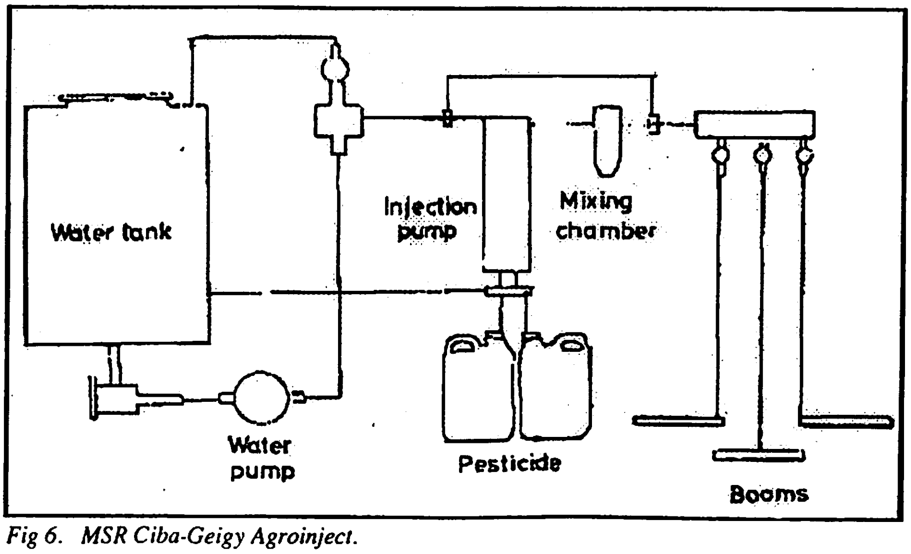
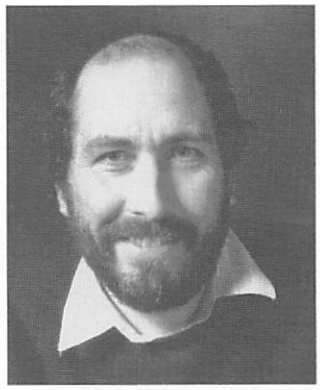


Fig 6. MSR Ciba-Geigy Agroinject.

Application of agricultural slurry to grassland using an umbilical fed applicator



Adrian Jones points out how some systems of slurry application can result in heavy trafficking and consequent crop losses. The latest anti-pollution legislation is likely to bring a large increase in the volume of slurry to be dealt with. The umbilical system of slurry application is seen as offering a significant reduction in trafficking and its associated adverse effects.

Increased trafficking on land with heavy machinery, often during adverse field conditions, has been common practice during the distribution of agricultural slurries on to land. Tankers holding between 1000 and 2000 gallons of slurry are commonly used and require a large tractor for safe and effective handling. Loss of productivity from trafficking has been well researched and demonstrated (Soane B D, 1983; Douglas & Crawford, 1991).

Fig 1. Drop pipe applicator connected to the umbilical drag hose and drawn by two wheel drive tractor.

A Jones is Specialist Adviser in Waste Handling at SAC, Auchincruive.

Latest legislation brings likely large increase in volume of slurry

Legislation recently introduced demands larger storage facilities on farms as a means of preventing application of slurry during winter conditions, where pollution risk may be high. The result is larger volumes of slurry are accumulated for subsequent application to land with relatively short envelopes of time available due to the crop or stock production system.

In order to apply slurries in an environmentally acceptable manner, maximum crop utilisation should be realised while minimising risk of pollution.

Umbilical system reduces trafficking, benefits production

The umbilical system operated at SAC Acrehead Unit, Dumfries, combines performance characteristics which can overcome some of the foregoing difficulties. Slurry is applied using a tractor

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pesticides on grass, fodder beet and cereals. The injection sprayer applied pesticide as well as a conventional sprayer. Trials were carried out to study the delay before pesticide reached the nozzles. A time delay exists due to the distance between the injection point and the nozzles.

Conclusions

- Increasing public awareness about the use of pesticides and the environment will result in pressure upon legislators to act accordingly. Existing and proposed legislation within the member states of the EC will encourage a raising of standards regarding pollution, particularly as 1993 approaches. The advantage of not having sprayer tank residues will interest many legislators.
- Direct injection closed systems offer considerable safety and environmental advantages by reducing operator contamination and removing the need to dispose of tank residues.
- Although the adoption of direct injection closed system sprayers will incur extra costs throughout the farming community, the undisputed advantages will far outweigh the increased capital costs.
- The ability to spot treat weed infestations, will be seen by many farmers as of great benefit in this period of falling returns.
- If returnable containers were adopted, many of the problems and expenses now faced by operators for rinsing and disposal will disappear. However, there are still problems to overcome due to the range of formulations and varying application rates.
- Container neck dimensional thread size standardisation to 63mm and 45mm by the members of GIFAP (International Group of National Associations of Manufacturers of Agrochemical Products) will allow further development of standard connectors and probes.

Acknowledgement

The author acknowledges the financial support given by Her Majesty's Agricultural Inspectorate, the Health and Safety Executive, and The Douglas Bomford Trust.

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In a subsequent issue of the Journal *we hope to publish a further paper by Andrew Landers in which he reviews the possibilities for utilising computerised information systems to minimise pesticide wastage.*

mounted applicator fed with slurry pumped through an umbilical drag hose (Warner N L, Godwin R J, Hann M J 1990). Weight and drawbar force is considerably reduced in comparison to using a trailed tanker. System throughputs are high and haulage from the storage tank to the field is eliminated. The operation of multiple tankers is necessary to match the overall work rates achieved. Slurry is applied through flexible drop pipes directly on to the ground surface without atomisation and associated emissions.

At Acrehead, slurry from a 140 cow Dairy Unit is collected in below slat storage prior to transfer into above ground steel stores, using a tractor driven pump. The system includes collection of washing water used in the parlour and collecting areas, silage effluent from roofed clamps and rainwater from associated clamp aprons and midden site. The Unit is almost entirely roofed therefore rainwater ingression is minimal compared with many farms. Dilution takes place from the addition of wash water and rainfall on the above ground storage tanks.

Agitation important to avoid variations in spreading

Prior to land application, the tank contents are well agitated by recirculation through a tractor pump. Good agitation has been regarded as an important feature to ensure reliability during operation of the system. Variations in 'dry matter' of the slurry become evident at application and by considerable variations in operational pressures.

Slurry is drawn directly from the storage tank and pumped through the main pipeline using a tractor driven scroll and stator pump. Power requirement is around 35kW. A hydraulic shut off valve on the applicator is used to stop the slurry flow through the applicator. The pressure increase caused by closing the valve is sensed at the pump causing it to divert and recirculate while the applicator valve is closed.

Transfer to the field site is by steel galvanised pipe laid temporarily above ground. Work involved in laying pipe is minimal and can be carried out in advance as it is not weather dependent. At Acrehead, 1000m of pipeline are used to give access to the complete unit of 82ha (all grass).

In the field the steel pipe terminates with a valve and connection to 200m of layflat drag hose transferring slurry to the tractor mounted applicator. The layflat hose is transported and handled using a shaft driven reeler which can be towed to the field behind the applicator.

The applicator receives slurry via a taper locked 'pull' coupling and valved restriction. Flow is through a 6m folding boom with layflat drop pipes distributing slurry directly onto the ground surface in bands. Limited pressure is maintained by the restrictor in the pipeline to prevent flattening of the feed hose particularly during turns.

One man system

During application the pump is controlled by pressure sensing alone, therefore the operation is carried out by one man only.

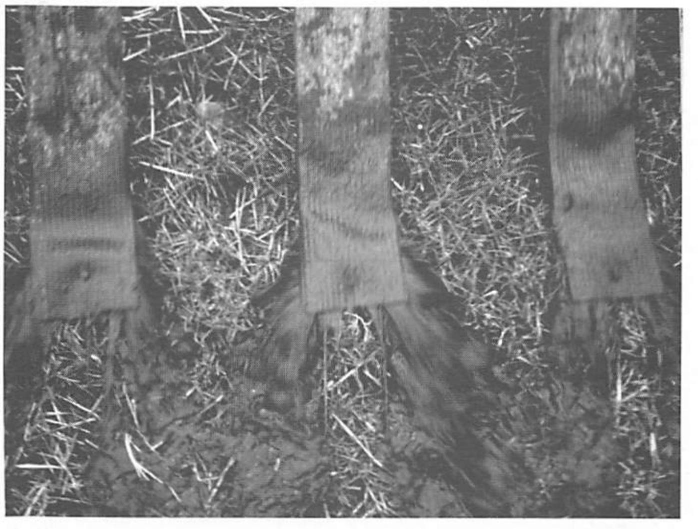

Fig 2. Distribution of slurry from drop pipes is directly onto the ground at low pressure with no atomisation.

Techniques have been developed to minimise pipe handling and application to a field site can be continuous without re-connection or handling of the pipe.

At the flow rates used (80-100m^3/hr) forward speed is adjusted to give a required application rate. In practice, the rate can be controlled accurately and remain consistent over a field area. Flow rate is adjusted by varying the pump shaft speed. At the flow rates used, application rate of slurry can easily be kept within those required by Codes of Practice.

Surface application reduces noxious emissions

Recent work carried out using a similar applicator but tanker mounted (Phillips V R, Pain B F, Clarkson C R, Klarenbeek J V 1990) has demonstrated certain advantage over 'spray type' application. Significant reductions in emissions are apparent due to non atomisation and application at ground level. Foliage between adjacent spread bands remains uncontaminated. More dilute slurries pass quickly to the ground surface again reducing leaf contamination.

Experience with the system has led to improved field techniques and development to improve reliability and ease of operation.

In summary, the system has resulted in a significant reduction in trafficking and associated effects. At Acrehead it has allowed a more planned approach to the application of slurry to grassland in a beneficial and environmentally acceptable manner.

The system can provide a viable alternative where there is an increasing demand to handle large volumes of slurry quickly, effectively and in line with current Codes of Practice.

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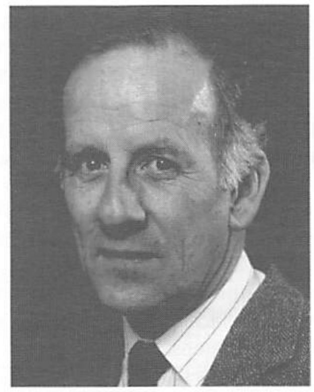
Grain dust – hazards, legislation, control



Since the introduction of COSHH (Control of Substances Hazardous to Health), ADAS Advisers have carried out many assessments of the personal exposure of workers to dust. The highest values are often recorded in mills and drying/storage units. Ken McLean here reviews the hazards presented by grain dust and explains how new regulations, introduced on 1st January this year, reflect the realisation that grain dust is potentially a serious hazard to health.

As long ago as 1713 in a discourse entitled 'Diseases of sifters and measurers of grain' Ramazzini noted that:–

> *"All kinds of grain, and in particular wheat, whether they are stored in pits and trenches or in granaries and barns always have mixed in with them a very fine dust. Not only the dust that they pick up from the threshing floor in the threshing but also another less innocent sort which is shed from the grain itself when it is kept for long.*
>
> *"Unless the seed is well dried in the summer sun before being stored it becomes overheated and soon crumbles to dust. The grain is further contaminated by residual dust and decay caused by the grubs, borers and weevils that consumed the grain.*
>
> *"Hence whenever it is necessary to sift wheat and barley or other kinds of grain to be ground in the mill or to measure it when corn merchants convey it hither and thither the men who sift and measure are so plagued by this kind of dust that when the work is finished they heap a thousand curses on their calling.*
>
> *"The throat, lungs and eyes are keenly aware of serious damage; the throat is choked and dried up with dust. The pulmonary passages become coated with crust and the result is a dry and obstinate cough. The eyes are much inflamed and watery, and almost all who make a living by 'sifting or measuring grain' are short of breath and cachectic and rarely reach old age."*

Workers in the UK have thus knowingly been exposed to the hazard to their health caused by grain dust for at least 276 years without the protection of statutory legislation.

COSHH Regulations – introduced September 1989

This situation improved with the introduction of the COSHH Regulations in September 1989 which listed "Dust of any kind, when present in a substantial concentration in air" as a "substance hazardous to health".

HSE Guidance Note EH40/91 'Occupational Exposure Limits 1991' gives details of the occupational exposure limits which should be used to determine the adequacy of control of exposure by inhalation of substances hazardous to health. The details which relate to specific hazards are contained in four tables:

- Table 1 – List of Maximum Exposure Limits (MELs)
- Table 2 – List of approved Occupational Exposure Standards (OESs)
- Table 3 – Changes to the list of approved OESs
- Table 4 – Substances to be reviewed.

Grain dust is not specifically referred to in any of these tables so currently is treated as a non-specific hazard.

Para 34 of EH40/91 states:–

"In the absence of a specific exposure limit for a particular dust, exposure should be adequately controlled and where there is no indication of the need for a lower value, personal exposure should be kept below both 10 mg/m³ 8-hour TWA (Time Weighted Average) total inhalable dust and 5 mg/m³ 8-hour TWA respirable dust. Such, or greater, dust concentrations should be

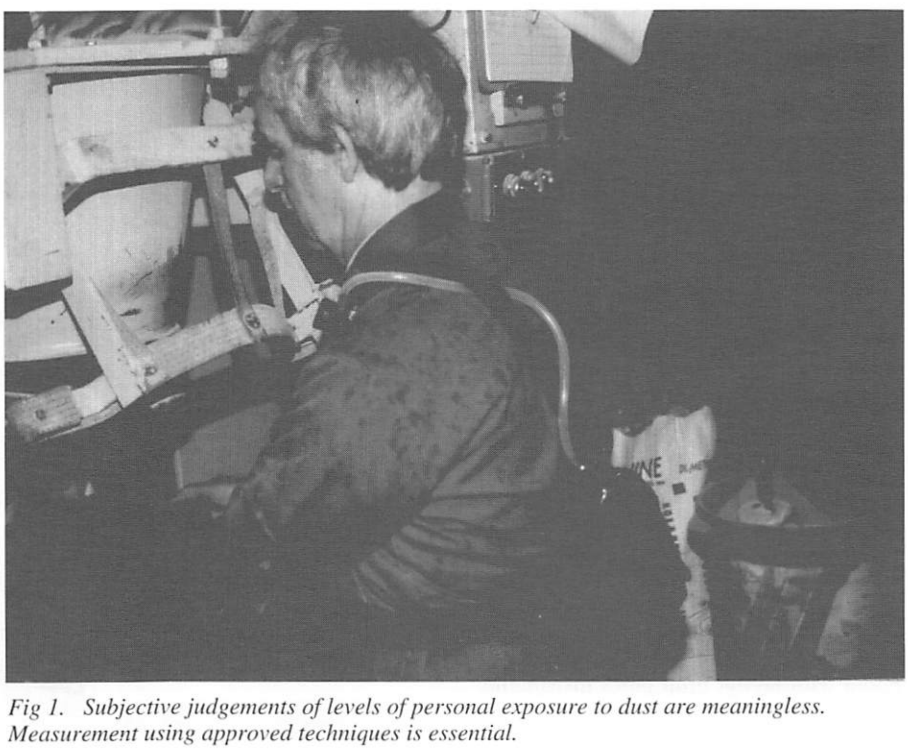


Fig 1. Subjective judgements of levels of personal exposure to dust are meaningless. Measurement using approved techniques is essential.

Paper presented to the Institution's Crop Drying and Storage Specialist Group.

K McLean is an ADAS Mechanisation Consultant based at Bury St Edmunds and author of the book 'Drying and Storage of Combinable Crops' published by Farming Press.

taken as 'substantial concentrations' for the purposes of Regulation 2 of COSHH and, as such, are substances hazardous to health."

This is the criterion which has been used by ADAS when carrying out assessments of workers exposure to dusts and can be compared with the results shown in the panel on page 16.

Grain dust – exposure limit now specified

From 1st January 1992 a MEL of 10 mg/m³ 8-hour TWA will be attributed to grain dust. The numerical value will not have been changed but the requirement of COSHH Regulation 7(4) will become pertinent:–

"Where there is exposure to a substance for which a Maximum Exposure Limit is specified in Schedule 1, the control of exposure shall, so far as the inhalation of that substance is concerned, only be treated as being adequate if the level of exposure is reduced so far as is reasonably practicable and in any case below the Maximum Exposure Limit."

Medical Advisers suggest that significant reductions in acute bronchitis symptoms do not come about until exposure to grain dust is reduced to 4 mg/m³ 8-hour TWA (Dopico *et al*, 1983). Hence it is to be expected that Inspectors will enforce control to levels well below 10 mg/m³ 8-hour TWA.

Complex nature of agricultural dust

Agricultural dust – possible constituents

Bacteria and bacterial endotoxins;
Fungal spores;
Mycotoxins including aflatoxins;
Mites and their excreta;
Weevils and their excreta;
Insect parts;
Animal hair and dander – from rodent infestation;
Feathers from pigeon infestation;
Rodent and pigeon excreta;
Pollens;
Silica;
Soil particles;
Fungicide, pesticide and fertiliser residues;
Non-grain plant materials including weeds, stems, etc.

Source: Howarth R F B, 1989

Numerous studies have confirmed that a spectrum of respiratory problems exists in agricultural workers, the multiplicity reflecting the complex nature of agricultural dust. Not all contaminants are important with regard to health effects and not all will be present in every sample of grain dust. However, the list does emphasise the need for everyone to take appropriate precautions when working in dusty atmospheres if respiratory disorders are to be avoided.

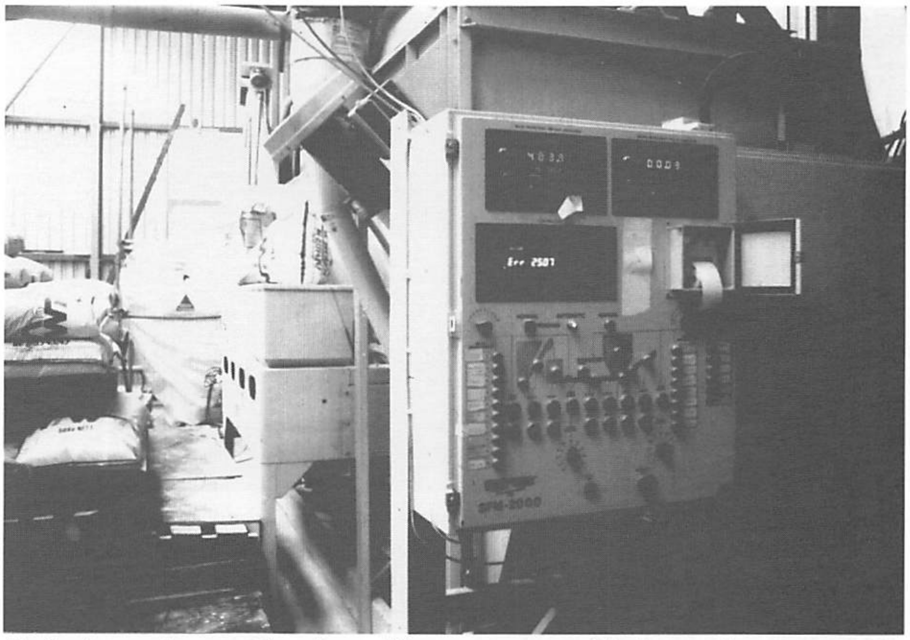


Fig 2. Automation can reduce the need for operators to work in dusty environments.

Table 1. Methods of control of exposure to dust on farms classified according to approach.

Method of control	*Approach technique*
1. Prevent particle formation	a. Reduce disease levels in field, reduce growth of field fungi.
	b. Prevent decay or insect and mite infestation of feeds and bedding stuffs.
	c. Use pesticide sprays minimally.
	d. Use techniques of feed preparation that minimise the formation of fine particles (feed pelleting, moist grain, feed additives, silage instead of hay).
2. Prevent particle release and dust cloud formation	a. Primary sources – capture dust clouds before they are released into the work space from point sources; well designed, leakproof ducting and conveyor systems for grain and concentrate feeds; dust canopies with cyclones or other dust trapping devices at air outlets of grain mills, conveyors, and elevators; well designed feed distribution systems in livestock buildings. Nonpoint sources of dust clouds (eg, fields during cultivation, crops during harvest) generally require other techniques, as in 5 below. Within enclosed livestock units, measures such as altering temperature and relative humidity, or lowering dust production from animal activity by adjusting stocking rate, or volumetric space per animal can also be used.
	b. Secondary sources – vacuum dust from floors, ledges, etc.
3. Remove suspended particles from enclosed workspaces	a. Ventilation – ventilation systems in enclosed livestock units, opening of windows and doors in barns (ventilation is ineffective in preventing short-term intense exposures to dusts close to dense point sources, eg, mouldy hay bale being broken open).
	b. Air cleaning by filtration.
	c. Air ionisation to precipitate particles.
4. Remove need for workers to be in dusty workplaces	a. Automate/mechanise processes to reduce need for operators to be in dusty workplaces, eg, micro-processor controlled milling systems, air swept grain storage systems.
5. Isolate workers from dust clouds in workplaces	a. This means providing a flow of filtered air for breathing, eg, tractor and combine harvester cabs with filtered air, discrete control / observation rooms in mills/driers, etc.

Fig 3. Workers can be isolated from dust by the use of cabs equipped with suitable air filtration systems.

Assessments of personal exposure to dust

(all results are for total inhalable dust expressed in mg/m³ on basis of 8-hour TWA)

workplace	*mg/m³*
Combining – with cab	0.2 – 2.5
without cab	18.3 – 41.0
Grain carting from combine	0.8 – 39.5
Grain drying – HSE	4.1 – 56.5
ADAS	2.4 – 40.8
Operation of seed plant	0.8 – 1.8
Operation of mills	2.0 – 351.0
Pigmen, daily routine	1.3 – 14.2
Broiler factories (hanging on)	4.4 – 44.5
Bulb grading lines	3.8 – 21.0
Potato grading lines	4.9 – 9.2
Onion grading lines	3.8 – 21.1
Timber yard operators	0.8 – 2.4

ADAS/HSE Investigations, 1989/1990

Methods of control of exposure to dust on farms

The approach to control of exposure to dust on farms should be by a combination of improvement in the design of systems and changing worker attitudes by education and persuasion. These two approaches must always go together. Alerting workers to the need to avoid the hazards of organic dusts without showing them how is pointless. Similarly introducing methods of dust control without persuading workers of the need to use them is counter productive. A dust control strategy is shown in Table 1 (Watson, 1986).

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Diseases associated with exposure to agricultural dust

Grain Fever (Organic Toxic Dust Syndrome): associated with facial warmth, raised temperature, headache, malaise, muscular pains, cough and phlegm, chest tightness and breathlessness.

The above symptoms are all of short duration and are associated mainly with young farm workers, exposed to very high dust concentrations. There is a high prevalence of symptoms in any given exposed group.

The cause is as yet not entirely clear but one possibility is bacterial endotoxin.

Extrinsic Allergic Alveolitis (Farmer's Lung Disease): this is associated particularly with work involving the handling of damp, mouldy hay and as one would expect there is a raised prevalence in areas with high rainfall.

The symptoms include breathlessness, dry cough, fever, sweating, nausea, muscle/joint pains, weakness and dizziness coming on between 4-10 hours AFTER exposure, lasting for 12-24 hours and the recovery occurs if exposure ceases.

If, however, exposures continue, weight loss is a common feature and eventually potentially irreversible lung damage is caused by scarring and fibrosis which leads to inefficient exchange of oxygen in the lung tissue. At this stage, Farmer's Lung Disease has serious long term implications; future exposure to mouldy hay has to be avoided totally.

NB: *Extrinsic Allergic Alveolitis is reportable under RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1985) on F2508 (Disease No.8). It is also a Prescribed Industrial Disease (B6) and Form NI226 should be obtained from the DSS.*

Occupational Asthma: it is important to note that asthma may occur in individuals who were previously entirely normal, in addition to those with pre-existing asthma/allergy. In the latter group, the dust can have a secondary irritant effect on airways which are already "twitchy"; exposure to high levels of dust can lead to "sensitisation" (the same as allergy) in a small percentage of those exposed (including those who were previously entirely normal).

The effects of exposure to dust are twofold:–

i) Immediate – causing irritation of the eyes, nose and throat
ii) Delayed – with chest tightness and wheezing from between 8-24 hours after exposure.

The delayed effects can be monitored using a mini peak flow meter, which is now available on prescription from general practitioners.

The implications for the asthma sufferer are potentially serious and long term and it is strongly advised that further exposure should be eliminated either by improved controls and high efficiency respiratory protective equipment (with adequate monitoring) or if this does not adequately control symptoms removal from exposure totally. The latter option may be extremely difficult if it has to entail a change of job.

Occupational asthma of this type is a Prescribed Industrial Disease (B7) and forms NI226 should be obtained from the DSS. It is also reportable under RIDDOR (Disease No.7) on form F2508A.

Chronic Bronchitis – is defined as: 'Cough and phlegm on most days for 3 consecutive months for at least 2 years'.

This would describe the average smoker's cough and as some studies appear to indicate that farm workers have a high prevalence of smoking, this was thought to be a factor. However, other studies have shown that there is in fact an increased prevalence in both smokers and non-smokers.

It is important to recognise that there is considerable overlap between the four categories of disease and the diagnosis is not necessarily clear-cut as many mixed patterns may exist. It is therefore very important that accurate diagnosis is undertaken by a physician with specialist expertise in chest diseases, particularly of an occupational nature (Wattie, 1990).

Dust control for the agricultural industry

John Whitehead

This paper was presented at a recent meeting of the Scottish Branch of the Institution.

Dust has been generated from the time man first started to grow his own food but increased mechanisation of the processes involved has intensified the dust problem. The introduction of the COSHH Regulations has added extra focus to the already appreciated dangers of the presence of dust in the working environment. Uncontrolled dust, however, does not only create unpleasant and uncomfortable working conditions, but can also:–

- **Cause occupational diseases**
- **Present an explosion risk**
- **Waste valuable product**
- **Cause machinery to fail**
- **Produce environmental pollution**

Out in the fields it is usually impossible to control dust effectively at source, so the only way workers can be protected is either by seating them in a correctly filtered and ventilated cab or by the use of personal protective equipment (PPE) such as ventilated helmets or face masks. It is important though that the correct type of PPE is selected and used. This will depend on the specific type and expected concentration of dust involved in each particular application. Far too often adequate protection is not provided for the worker because the PPE used has been incorrectly selected or simply does not fit properly.

Indoor operations – control dust at source

Within farm buildings, at mills, and at other facilities such as seed and bulb preparation areas it is quite a different matter. Dust control at source is usually perfectly possible, although the correct method of capture should be used if a good standard of control is to be achieved without excessive cost.

In starting to assess the way in which control should be applied to a dusty operation, the dust control engineer must first study the operation closely to ensure that equipment installed to minimise dust will not seriously inhibit existing and well proven working practices. This is essential to ensure that a solution is not provided which is acceptable from a dust control engineering point of view, but is not sympathetic to the requirements of the equipment operator.

Once the designer has observed the operation closely, a system must be designed which utilises the minimum amount of 'control air' possible to achieve a good level of dust control. This may take the form of providing localised hoods at each dust generation point or the use of an enclosure around a number of these points. In some cases a combination of these two methods of approach may be considered to be the best solution. Consideration should also be given to the need for access for cleaning and maintenance and, in general, all designs should have a minimum of ledges or 'dust traps'.

J Whitehead is UK Sales Manager, DCE Ltd., Leicester.

Local proximity hoods for free standing operations

The use of a local proximity hood applied to a drum filling operation is shown in Fig 1A. This hood is designed to pull a curtain of air over the top of the drum to capture the dust created while materials are being tipped into the drum.

The hood is shaped around the periphery of the drum to ensure that the hood face is

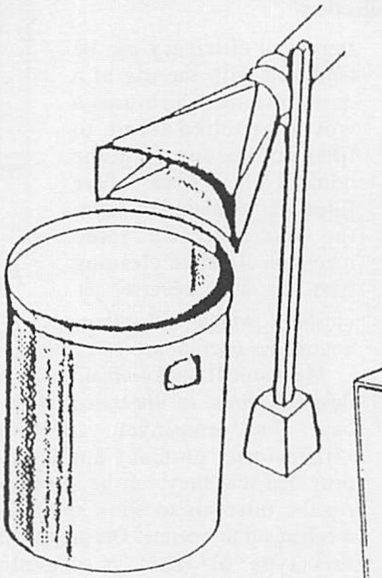
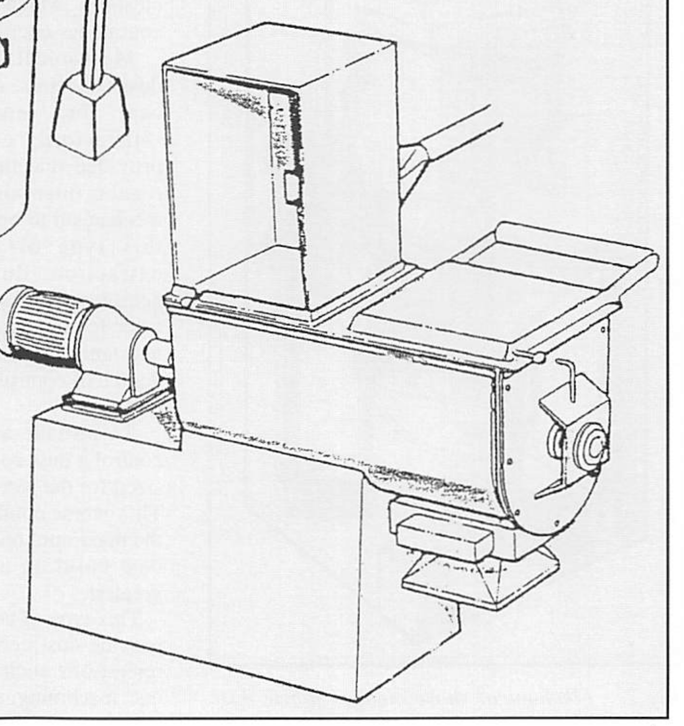


Fig 1A (left). Use of a local proximity hood.

Fig 1B (below). Use of an enclosure.



as close as possible to any possible point of dust escape, as effectiveness of an open face hood diminishes rapidly as the distance from the face increases.

A simple formula for calculating the quantity of air (Q) required to provide a capture velocity (V) for a dust at a varying distance (X) from an open hood of face area (A) is:-

$$Q = V\,(10X^2 + A)$$

This simple formula is only applicable to square or round plain faced hoods, as the calculation becomes more complex for rectangular or flanged faces, but it does show quite clearly that hoods must be positioned as close as possible to the dust source to minimise the quantity of control air required.

Enclosures – for fixed locations

Control of the dust created when loading a mixer, as shown in Fig 1B, is by the use of an enclosure rather than a local proximity hood.

Using an enclosure, the dust control engineer is seeking to contain the dust created by providing a controlling air velocity of typically 1m/sec across the open face of the enclosure through which the materials are being loaded.

This is a very effective method of dust control as an enclosure eliminates the possibility of cross draughts which can be detrimental to the effectiveness of local proximity hooding. Open doorways, movements within the vicinity of the dust source or air currents created by heaters can all serve to create draughts that can reduce the efficiency of local hooding.

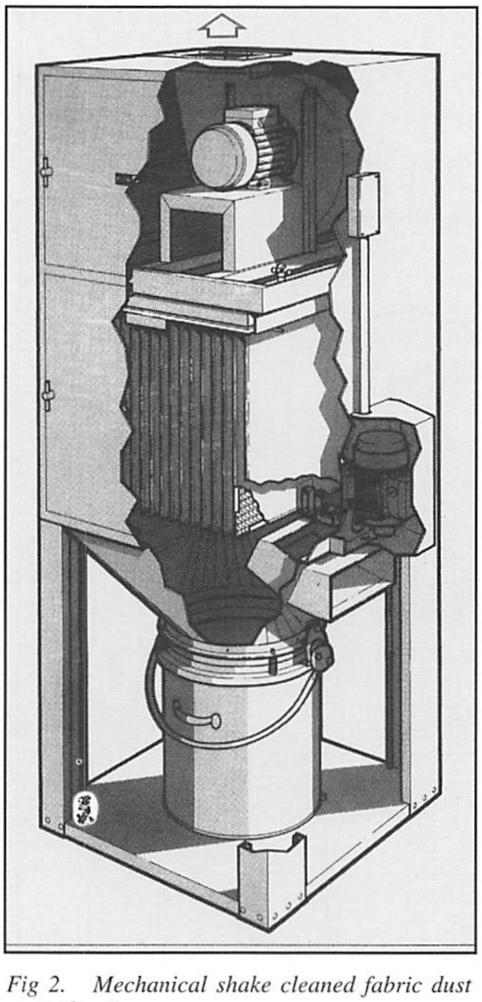


Fig 2. Mechanical shake cleaned fabric dust control unit.

Dust collectors

– Cyclones the traditional method, but less effective with fine dust

The traditional method used in the agricultural industry for separating and collecting the dust from the control air has been by the use of a cyclone.

The efficiency of separation provided by cyclones is not particularly good when fine dust is involved and there is invariably some degree of dust carry over in the cleaned air discharged from the cyclone. This will usually mean that this air has to be vented out of the building taking with it heat which is expensive to replace.

– Fabric filters – for intermittent or continuous collection

Improved efficiency can be achieved with the use of a dust collector which uses a woven or felted fabric to filter out the dust from the control air. These fabric filters are available in either the intermittently rated mechanical shake cleaning type or with reverse jet cleaning which will allow continuous operation.

Mechanical shake cleaning fabric dust collectors, as illustrated in Fig 2, can be employed perfectly satisfactorily on many applications provided that they can be stopped at regular intervals to allow the shaker mechanism to operate. During the time this type of filter is providing extraction, dust is progressively accumulating on the surface of the filter fabric and creating an increasing resistance to air flow. This reduces the degree of control at the dust generation points.

To provide an acceptable level of control a dust collector must always be sized for the worst operating condition. This worst condition is at the end of the maximum operating cycle when the dust build up on the fabric is at its greatest.

This type of collector can be used to provide dust control for many manual operations such as tipping, weighing out, machining, mixing and even short duration mechanical operations such as lorry loading and unloading and silo venting.

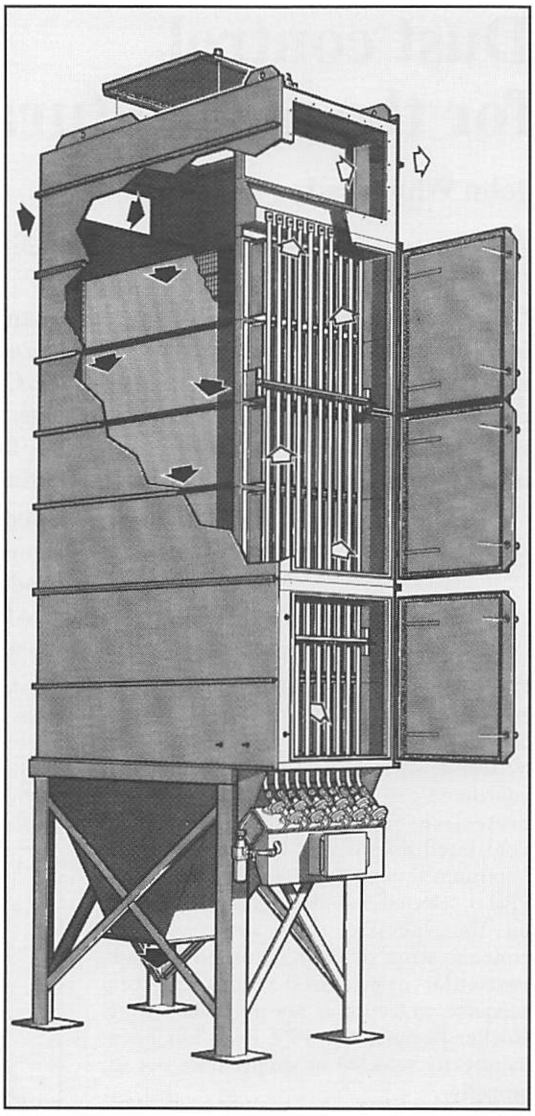


Fig 3. Reverse jet cleaned fabric dust collector.

Reverse jet compressed air cleaned fabric dust collectors, such as illustrated in Fig 3, operate at an almost constant resistance to air flow, due to their ability to remove dust from the fabric surface whilst in operation. The total quantity of control air can, therefore, largely be relied upon to remain unaltered during operation.

The reverse jet cleaned fabric type of collector can operate for long uninterrupted periods handling high dust loads and so is ideal for use to control dust in processing plants on such equipment as dryers, screws, conveyors and elevators.

Explosion risks

Finely divided dust from organic materials is potentially explosive. If an ignition source is present in a dust cloud of a concentration that is between the upper and lower critical limits for that particular material there is a high probability that there will be an explosion.

It is important, therefore, that such dust clouds are prevented from occurring

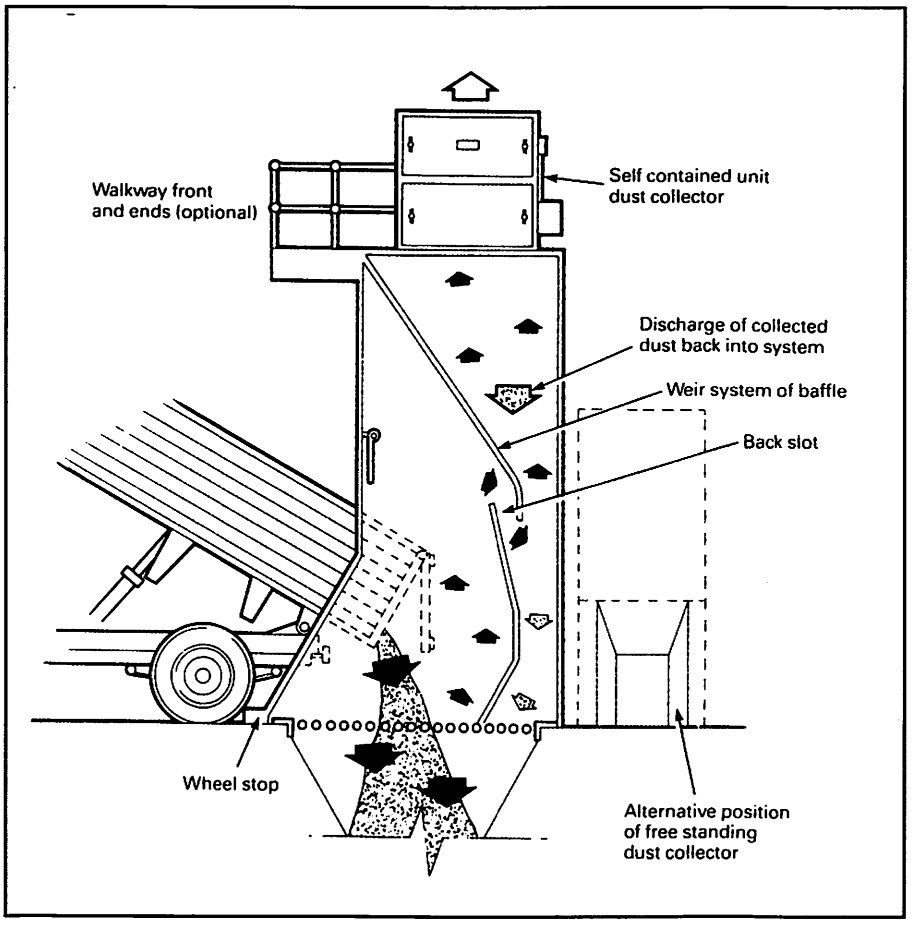


Fig 4. Outline design of a lorry tipping booth with integral dust control equipment.

that buildings are kept as clean as possible. Dust resting on ledges can be ignited in the event of an explosion to create a secondary explosion which would normally be far more severe than the original one.

Dust collectors handling potentially explosive dusts must be capable of coping with an explosion should one occur within them. The most common method is to provide an explosion relief panel on the dust collector which will fracture and relieve the very high explosion pressures involved. The dust collector should also have enough mechanical strength to handle the initial rapid pressure rise which will develop before the relief panel fractures.

Venting ducts should ideally be provided for all internally located dust collectors to convey the explosion gases and flames to atmosphere eliminating the risk of a secondary explosion or an internal fire.

Feed mills – a critical area for control

Within the agricultural industry one of the major areas requiring dust control equipment is in animal feed mills. Dust control is required throughout the mill from initial raw material reception right through to the despatch of the finished products.

Raw materials most commonly arrive by road but they can also come in by rail, ship or barge. Whichever method is used dust control will be required if pollution and wastage is to be minimised.

Fig 4 shows the design and air flow pattern of a typical lorry tipping booth which will both control the dust during the tipping operation and return the collected dust into the system when the operation is complete.

Dust filters are also required to vent silos which are pneumatically filled from road tankers.

It is essential that competent dust control engineers are used to design systems required to handle the dust created during bulk rail deliveries and grab unloading from ships as both require a high degree of expertise and experience to provide good cost effective solutions.

Once the raw materials are inside the mill, dust control will be required for handling equipment such as elevators, conveyors, screens and storage bins. Additionally grinders, pellet coolers and the processes of dispensing and adding drugs into the products will all need careful consideration of their dust control requirements as will the despatch of the finished products whether into bags or in bulk.

Practical actions

It may seem obvious, but the best way of controlling dust is to prevent it being formed or released in the first place.

Much can be achieved by good housekeeping and sensible operating methods.

Simple actions such as keeping lids on drums and turning down the tops of bags can reduce the risk of spillage and dust generation. Totally or partially enclosing a process will reduce the amount of dust that will escape into the general atmosphere and therefore minimise the amount of air required to give good control.

Many locations may have a number of potential dust sources which require to be controlled but often not all of these are active at the same time. If this is the case an alternating system can be installed which allows each exhaust point to be shut off when not in use. Such a system should be sized to cater for the maximum number of dust sources that are possible at any one time which may be considerably less than the total number. The dust collector for such a plant will quite clearly be smaller and less expensive than one which is designed to handle the exhaust from all of the points at the same time.

By considering practical actions such as these the volume of dust generated and released into the working environment can firstly be minimised and then economically controlled by means of a well and carefully engineered dust control system.

BOOKS

Farming for Feedstocks, Fuels and Fibres (Proceedings of the Stoneleigh Conference, November 1990)

Edited by Y R Alston, J Coombs
Publ: The Biomass and Biofuels Association, Reading. 164 pages, £25.

The call is on for more non-food crops on British farms and the Conference, Farming for Feedstocks, Fuels and Fibres has produced a useful report giving a broad overview of opinions, options and prospects.

In the opening session of the Conference Professor Bryn Green of Wye College, University of London sets out 'the size of the market'. His figures indicate that up to 6m acres of current British farmland will be surplus to food production needs by the end of the century.

Other speakers deal in detail with particular non-food crops; their likely costs and market prospects. A broad conclusion of the Conference might be that alternative crops may not in themselves offer competitive supplies but there is now a political will and a social will to pay a little more to help improve the environment. Possibly even a tax (a disposal cost) on some current materials might help balance the picture.

Some 20 well-qualified speakers presented papers at the Conference and these Proceedings contain much valuable data on the properties, performance and applications of possible non-food crops.

GGB

Use of controlled atmosphere generators to treat grain

Chris Bell

This is a synopsis of a paper presented to the 5th International Working Conference on Stored Product Protection.

The last few years have seen a steady increase in interest in the use of controlled atmospheres as a means of controlling infestations of insects in grain.

More recently this interest has been enhanced by the increasing awareness of toxic side effects arising from the use of chemicals, particularly those that have enjoyed long term usage, and by the demands from consumers and society in general for significant reductions in the use of pesticides.

There is currently public suspicion of any chemical of a persistent nature whether or not evidence is available of any adverse side effects, and the prophylactic use of pesticides to protect crops may soon carry financial implications for trading, because of the desire for residue-free foods.

Continuous flow system the only practical method

Limitations that have prevented the more widespread adoption of controlled atmosphere techniques are the long exposure times required for control of pests, the belief that treatment costs will prove to be high, the apparent lack of specialist equipment for providing suitable gas, and a lack of technical expertise in setting up the precise arrangements for physically applying the gas to the store.

There is a need firstly to achieve the complete replacement of air during the initial purge and secondly to maintain successfully the new atmosphere for the period necessary for pests to be killed. Because few existing structures are gas tight, it has long been realised that continuous flow systems offer the only practicable method for treatment.

Construction of prototype generators

For a number of years research at Slough has been addressed to the problems of gas application methods and to the development of a suitable gas generating device.

For the UK grain industry – with the withdrawal of the old liquid fumigants long relied on for control – the need for a reliable non-chemical method was apparent, but in spite of the pioneering work done in the USA (Storey, 1973; 1975; 1980) and in France (Fleurat Lessard and Fuzeau, 1984; Fleurat Lessard and Le Torc'h, 1987) no suitable instrument was available for purchase by farmers, grain store managers or pest control companies.

Hence the current programme was started as a joint venture between the Central Science Laboratory at Slough and The Aerogen Company Limited to develop a transportable propane-fuelled burner device that could be used to treat grain held in a wide variety of situations, and to establish the parameters necessary for its successful use.

The controlled atmosphere was produced using a premix propane burner which was installed in a chiller unit to remove the moisture generated by the combustion reaction. The maximum flow rate was 17 $m^3\ h^{-1}$ at temperatures several degrees below ambient and oxygen content <1%. The prototype incorporated all relevant safety features.

Two prototype generators have been tested during the experimental programme. Both incorporated an open flame burner unit in a closed vessel with fan assistance to reduce back pressure and with a self-regulating fuel and air supply.

Laboratory trials

Pilot scale trials at the Laboratory were conducted in welded steel bins of $19m^3$ capacity held on metal supports under cover in a barn, and featuring a hopper base for unloading. Gas sampling lines at 1m intervals and a central thermocouple were attached to a steel cable run from inside the hopper to the bin apex. Each bin was then loaded with 12t feed wheat.

These bins were relatively gas tight and the gas tightness was adjustable for experimental purposes by alteration of the degree of seal at the 30mm apical port through which the gas sampling lines and thermocouple were fed out of the bin. For the current tests a pressure test half life of 2.5 min was obtained.

Gas was introduced at flow rates ranging from 3–6$m^3\ h^{-1}$ via a 150mm aeration port in the side of the hopper and using a modified plate to receive the 50mm dia flexible outlet hose of the generator. The progress of gas through the silo was monitored using a paramagnetic oxygen analyser and an infrared carbon dioxide analyser.

Fig 1. Farm trials in 180 tonne wheat showed that a controlled atmosphere can give a high level of kill of pest beetles.

On farm trials with two species of pest beetles

For this experiment, conducted in May, a farm bin containing 180t of wheat cv Avalon dried to about 14% moisture content was selected. The bin was free-standing but featured a permanently installed auger leading to an adjacent barn.

Dr C H Bell is Head of the Fumigation and Controlled Atmospheres Branch at the Ministry of Agriculture, Fisheries and Food, Central Science Laboratory, Slough.

A 65mm port was present at the base for aeration purposes and this was modified to receive the flexible hose outlet of the prototype burner. For the treatment, the auger was uncoupled near the barn and sealed with polythene.

Working on the grain surface, nylon gas sampling lines of 2mm bore, thermocouples and caged laboratory samples of 100 adults of two beetle species, *Sitophilus granarius* (L) and *Cryptolestes ferrugineus* (Stephens), were inserted in pairs at 1m intervals down to 4m depth in the grain at the bin centre and at the side near the access hatch. Control samples were inserted in an adjacent bin. The grain surface was then sheeted over with polythene which was tucked into the grain at the sides.

The gas generator was started and the product gas was monitored to ensure that oxygen levels were well below 1% and that carbon dioxide levels exceeded 12%. The connection to the silo was then opened and purging commenced at the rate of $8m^3 h^{-1}$ of gas flow. This was later increased to $10.5m^3 h^{-1}$ and thereafter, on achieving the replacement of the atmosphere, the flow rate was repeatedly adjusted to ascertain the level of input required for maintenance of less than 1% oxygen throughout the grain.

After 14 days operation, the burner was switched off and the disappearance of the applied atmosphere was monitored over 24 hours before unsheeting and removing lines and insect samples. At the laboratory, insect samples were examined for survival after 14 days.

High levels of kill even over short duration trial

The grain surface within the bin formed a shallow cone so that the grain depth reduced from nearly 6m at the central apex to just over 4m at the sides.

During the initial stages of introducing gas, billowing of the sheet over the grain surface was observed and a slit was cut in the sheet near the apex to allow the atmosphere to vent freely. The gas flow rate was then increased to $10.5m^3 h^{-1}$ and with the exception of the region near the apical slit, oxygen levels fell to 1% or below throughout the bin within the next two days.

The temperature of the exhaust gas released from the burner was 6-12°C below the ambient temperatures of around 20°C.

Assuming an interstitial volume of just over $100m^3 h^{-1}$, based on 45% of the stowage volume for 180t of wheat ($225m^3$), oxygen levels were brought to 1% by 5.2 atmosphere changes. Wind speeds ranged from 0.5 to $1.5ms^{-1}$ during the purge.

Because the trial did not extend beyond a 15-day period, test insects were not all killed. Their survival pattern reflected the conditions which prevailed during the trial.

Laboratory studies have demonstrated that at stable concentrations adults of both *C. ferrugineus* and *S. granarius* require 6-7 days exposure at 1% oxygen for kill at 20°C (Krishnamurthy *et al*, 1986) but at no position in the bin did oxygen levels remain below 2% for longer than ten days, and grain temperatures were generally much lower than 20°C.

Nevertheless, as can be seen from the Table, high levels of kill were obtained of both species.

Conclusions – no special preparations needed for successful treatment

The experiment with the 180t capacity farm bin illustrated that no special preparations beyond those performed for fumigation were necessary for the successful use of a controlled atmosphere treatment to kill insects in grain.

Table 1. Mortality of adult *Sitophilus granarius* and *Cryptolestes ferrugineus* exposed to burner gas in a bin containing 180 tonnes of wheat.

Sample position and depth	*Days below 2% O_2*	*Mean temp (°C)*	*S.granarius (% kill)*	*C.ferrugineus (% kill)*
Centre 4m	10	11	99	100
Centre 2m	7	13	91	100
Centre surface	3	15	13	56
Side 4m	10	16	99	100
Side 2m	9	17	100	100
Side surface	8	20	91	89
Control	0	12	9	30

The self-cooled gas generator was capable of producing a sufficient supply of gas for extended periods at a temperature several degrees below ambient, and the strategy of continuously introducing gas was able to prevent any localised areas of intermittently high oxygen levels occurring in the bulk.

The grain, at an average moisture content of 14% and with mean temperatures ranging from 11°C to 20°C, contributed to the modified atmosphere obtained by removing both oxygen and carbon dioxide from the generator exhaust gas, the former probably by microbial activity and the latter by physical sorption. A similar result was obtained with grain above 14.5% moisture content at 13°C to 18°C in earlier trials in the welded steel bins with simulated burner gas (Bell, 1987).

A critical factor in determining the gas flow required to hold an applied atmosphere was wind speed. The smaller the structure the more critical this factor becomes because of the ratio between volume and surface area. For every doubling of volume in structures of similar shape, surface area increases by a factor of less than 1.6, and hence the potential rate of leakage, assuming a similar distribution of small multiple leak sources, is reduced by over 20%.

Thus the cost of treatment per tonne of grain is likely to reduce as the size of the grain bulk is increased.

For a bin holding 150t of grain, the cost of propane required to control all stages of most common pests would be in the region of £1.30 to £1.50 per tonne of grain.

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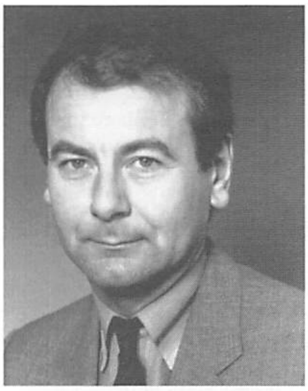
This Controlled Atmosphere Invertebrate Pest Control System is to be marketed by the Aerogen Company Ltd under the name Aerogenerator.

Tyres as an influence in machine design

Today it is not enough to fit machinery with the cheapest and simplest wheel equipment, says Stephen English. The tyre must be regarded as part of the cultivation and harvesting system in forestry management. Today's tyre is a complicated creation that has to work under many different conditions and at the same time is required to have properties that are difficult to combine.



Mechanisation in forestry has moved extremely rapidly and is today highly developed. Efficient and mechanised forestry requires effective interaction between the machine operator, the machine, the soil and the crop. Each job must be done in a correct manner and at the right time.

Profitability in the enterprise is largely dependent on this interaction. In addition, attempts are always made to achieve high efficiency and capacity. Over the years soil compaction has become an increasing problem in pace with the increases in machine size and weight. Demands for rationalisation in forestry have enhanced this development.

Originally the importance of the tyre was not considered. However, research and practical experiences have led to increased interest in tyre equipment permitting lower inflation and pressure, and thus leading to less soil compaction and damage to the soil.

Machines can now do all the operations that were earlier done by fellers and horse and driver. Felling costs have also decreased in pace with the increase in mechanisation. In many respects this development has been positive, but there are also negative aspects. Damage to trees and to the soil have increased largely as a result of incorrect wheel equipment and heavier machinery.

The machinery manufacturers' 'ideal tyre'

The type of work to be carried out and the working environment place demands on machinery manufacturers who in turn place demands on tyre manufacturers. It is certainly true to say the forest tyre of the 1990s has been developed in conjunction with the machinery manufacturers. So what are these manufacturers looking for?

- Low surface pressure
- Suitably gentle tread pattern
- Round shoulders
- Low profile
- Little track formation
- Durable design
- Good carrying capacity
- Off-road mobility
- Long life
- Reinforced rims
- Comfort for the operator

S V English is UK Sales Manager, Trelleborg Tyre Division.

Firstly we could ask ourselves why do we need a tyre, tracks could be an alternative and indeed are starting to appear, albeit in relatively low numbers: for example, German excavators with harvesting heads fitted to the boom ends. However, tracks do have a number of drawbacks:–

- Tracks need to be very wide to give low surface pressure;
- Steerage mechanism churns up the surface mat;
- Low in tractive power;
- Very slow roadspeeds and generally inappropriate for highway use;
- Unable to absorb surface irregularities;
- Expensive to maintain;
- Very uncomfortable for the operator.

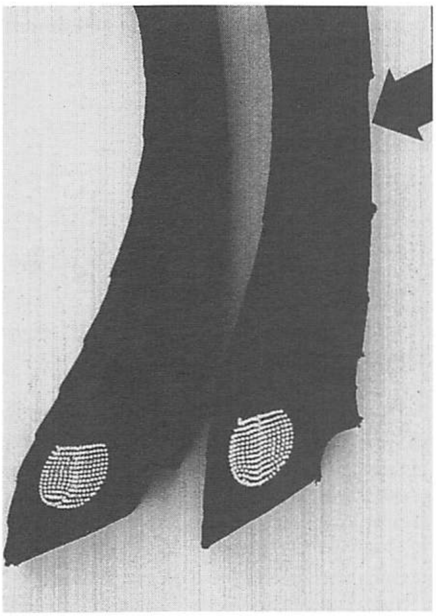


Fig 1. Section of forestry tyres showing extra thick side wall to give added protection on rough stony ground.

Without dwelling any more on tracks, let us assume our machinery manufacturer has decided to use a tyre which of course over 90% do. What then is a tyre?

- A tyre must be able to carry a load and function as a suspension element. Often on forestry machines the tyre is the only form of suspension.
- It must withstand radial deformation.
- It must withstand rotational deformation and have a high grip: high friction on hard ground, strong hold on loose soil.
- It must withstand point loading and be capable of absorbing surface irregularities.
- It must withstand lateral deformation when cornering or driving on sloping land.

In addition to the above, tyres must also:–

- Absorb stresses when driving and braking.
- Be wear and cut resistant.
- Have resistance to fatigue, heat and cold.
- Be durable.

Tyre construction for arduous duty

Clearly a lot is being asked of the tyre. Its construction is critical. Important features include the following:–

The carcass is the reinforcement in the tyre that ensures shape, profile and strength are fulfilled according to the given requirements. In order to make the carcass resist the forces working on the tyre it must itself be reinforced. This is done by building up a body of textile fibres in a certain amount of plies to obtain the strength desired. The structural strength obtained is known as the *ply rating*.

A new *durability rating* is now starting to appear instead of ply rating. This consists of two index codes, one for load and another for speed. LI is *load index,* which states maximum load at a given speed. *Speed index* gives the speed. In order to interpret these codes, reference must be made to the

Table 1. Speed index – code symbols applicable to tyres used in forestry.

Speed symbol	*Speed km/h*
A1	5
A2	10
A3	15
A4	20
A5	25
A6	30
A7	35
A8	40

The SPEED SYMBOL indicates the speed at which the tyre can carry a load corresponding to its Load Index under service conditions specified by the tyre manufacturer.

industry standard tables which give the speed and load design limits corresponding to each code number or letter. An extract from these standard tables is presented in Tables 1 and 2 covering the codes relevant to forestry tyres.

Table 2. Load Index – code values applicable to tyres used in forestry.

LI	kg	LI	kg
140	2 500	160	4 500
141	2 575	161	4 625
142	2 650	162	4 750
143	2 725	163	4 875
144	2 800	164	5 000
145	2 900	165	5 150
146	3 000	166	5 300
147	3 075	167	5 450
148	3 150	168	5 600
149	3 250	169	5 800
150	3 350	170	6 000
151	3 450	171	6 150
152	3 550	172	6 300
153	3 650	173	6 500
154	3 750	174	6 700
155	3 875	175	6 900
156	4 000	176	7 100
157	4 125	177	7 300
158	4 250	178	7 500
159	4 375	179	7 750

The LOAD INDEX is a numerical code associated with the maximum load a tyre can carry at the speed indicated by its Speed Symbol under service conditions specified by the tyre manufacturer.

The belt is an extra reinforcement placed between carcass and tread. The function of the belt is to stabilise the tread and to protect the carcass from damage by sharp objects. In forestry the belt frequently consists of steel ply to provide additional protection and stability.

The bead consists of a cable made up of twisted steel wires for desired durability. The layers of ply of the inner lining are folded around the wire cable to hold it in place. The cable makes the bead very strong and rigid which is essential as it is here that the torque between the rim and the tyre is transmitted.

The tread is a thick layer of rubber in which the pattern is made. Rubber quality chosen will depend on the tyre's intended use and thickness which affect pattern and depth.

The sidewall covers and protects the wall of the tyre between the tread and bead. The rubber material is generally the same as that in the tread, but sometimes may have special properties depending on the tyre's intended type of use.

As forestry tyres are subject to having their sides cut by stones, stumps, etc. it is desirable to reinforce the sides as shown in Fig 1. This enables the tyre to withstand these stresses better.

From Fig 1 you will note how the sidewall of the tyre is extended to give rim edge protection. This is essential on a forestry tyre to protect against splinters and small stones forcing themselves in between the tyre and the rim thus puncturing the tube.

The rubber mixture is a very complex subject which I do not intend to go into in this paper, other than to mention that natural rubber has excellent wear, tear and traction resistance properties – all essential requirements of a forestry tyre. Synthetic rubber is widely used nowadays in conjunction with natural rubber basically because it is much cheaper. However, the mix is a compromise whereby certain properties are improved but others are impaired. A higher percentage of natural rubber is used in forestry tyres because of its positive wear, tear and traction resistance characteristics. This is one of the main reasons why they are more expensive.

Advantages of bias belt tyre design for forestry

There are two principle types of tyre:–

A Cross ply
B Radial

In addition there is type C, the bias-belted tyre, which is a combination of diagonal and radial tyres. The bias-belt design is widely used in forestry applications and offers the advantages of both radial and cross ply without involving many of their disadvantages:

- Good all round properties;
- Good grip and comfort;
- Strong walls and carcass, capable of withstanding low inflation pressure;
- Good lateral stability;
- Low rolling resistance on soft surfaces.

Importance of tyre profile

The profile affects the properties and performance of the tyre. Low profile tyres have better lateral stability and less risk of folding when exposed to high torque. Also when the outer diameter is constant a low profile tyre uses a larger diameter rim. This, together with the larger rim to bead seat area (explained later), makes the tyre capable of transmitting much larger driving forces without the risk of rim tyre slippage.

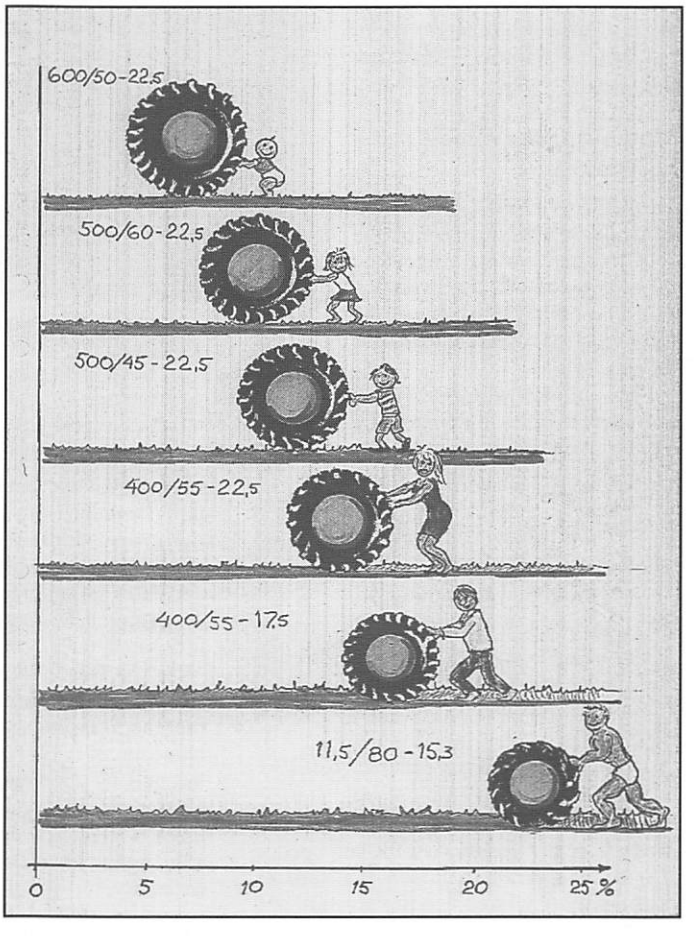


Fig 2 Wheeling resistance decreases as wheel diameter goes up and inflation pressure comes down.

Generally speaking the lug height on forestry tyre tread patterns should be low in order to avoid ripping up the surface. Tread pattern design, however, is a compromise to achieve maximum:

- traction;
- side grip;
- self cleaning.

A cornered section profile gives a large contact surface with resultant good grip. However, it gets easily caught on obstacles in rough terrain and can result in tread bars being ripped off. The rounded profile glides away from obstacles, is kinder to the ground and does not cut up the surface so much.

As many forestry machines have driven rigid tandem axles this must be borne in mind by tread designers. When two wheels are mounted on a bogie the result is that the front wheel works inwards in a curve whereas the rear wheel works outwards. Forces are therefore generated at right-angles increasing the stress on the tyre, rim and axle. The track created will be wider than the tyre and if the tyre is narrow with an aggressive tread pattern the surface will be rutted and ripped up. These effects are reduced by fitting a wider tyre with a non-aggressive tread pattern, utilising rounded shoulders.

Minimising the rolling resistance

The depth to which a wheel sinks depends on the softness of the soil, the load on the wheel and the tyre's contact area with the soil. The rolling resistance is the force required to roll the tyre over the soil surface.

To achieve a low rolling resistance on a soft surface requires tyres with:

- large diameter;
- large width;
- low inflation pressure;

all of which combine to give:

- lower power requirement;
- reduced fuel consumption.

Fig 2 shows some examples of wheeling resistance of a few tyre dimensions. Wheeling resistance is calculated on a % basis according to:

$$\frac{\text{Propulsion force}}{\text{Load}} \times 100 = \text{Friction coeff (\%)}$$

The practical conclusion is therefore to use as large a wheel as possible and operate it with as low an inflation pressure as possible. Low ground bearing pressure and low rolling resistance will also minimise wheel rutting.

The load capacity of a tyre is not only governed by the inflation pressure but also air volume. This can be illustrated by the example of two pistons where one has double the surface area of the other. At the same height the larger piston takes the same load as the smaller one at half the inflation pressure but twice the air volume.

A narrow tyre has a small air volume and requires a high inflation pressure to support the load. A wide tyre has a large air volume which will support the same load at a lower inflation pressure.

As we have seen, a big, wide tyre has a

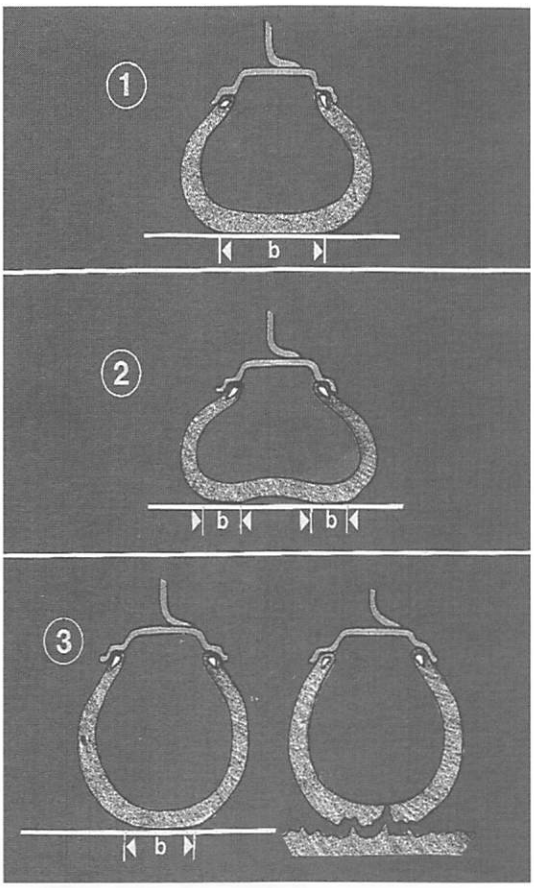


Fig 3 Incorrect tyre pressures cause tyre damage/reduce performance.
1 = the norm
2 = too low – side wrinkling creates heat accumulation which will eventually destroy the carcass
3 = too high – increases soil compaction, reduces pull

large air volume and can be driven with low inflation pressure. Surface pressure therefore decreases and the soil is compacted less. The track depth also decreases considerably and by not sinking down so much, deeper compaction damage is reduced.

As the tyre inflation pressure is lowered the area of contact with the ground increases as does the tractive ability. A reduction of tyre pressure by 45% increases the pull by 22% on soft ground. Inflation pressure is governed by load and speed but there is great advantage in not running at any higher an inflation pressure than is necessary.

Forest soils easily damaged if tyre pressures incorrect

In the forest environment, when deep ruts are formed, sensitive aerial roots are damaged and this hampers the trees' growth and increases the risk of decay. Forestry soil is also sensitive to compaction. The thin layer of debris on the surface largely supplies the trees with nutrients. Damage to the surface layer takes a long time to recover and the surrounding trees suffer from growth losses. Also if deep tracks are formed they may have the effect of draining the surrounding soil and alter the water supply over large areas.

Illustrated in Fig 3 is the importance of using correct tyre pressures.

Wheel rim is also crucial to performance

In Fig 4 we see a standard rim with a 12mm centre plate. There are two principal types of rims:– Flatbase and Drop-centre.

Flatbase is a split rim or one where the rim edges may be removed and are fixed by a clamp ring. A drop centre rim is one where there can be either a 5° or 15° angle at the bead seat area. As we have seen the transfer of tractive power between the machine and tyre takes place at the bead. It is important the tyre grips properly. Consequently the seating is angled, which ensures that the tyre assisted by inflation pressure is forced up against the rim edge. Rim diameters of 864mm and 965mm have a tyre seat slanting angle of 5°. All others use 15°. The advantages of 15° angle rims are:

- Easier mounting, especially of high ply rating steel belted tyres of a small rim diameter;
- The larger seat area minimises risk of tyre sliding on rim and transmits greater pull.

On forestry machines, where wheels are exposed to large external forces, the rim edges must be strengthened (Fig 5). Round bars or flat bars (round being the norm) can be welded to the rim edge. Also available, and now fitted to some Scandinavian OSA machines, is rolled edge reinforcement, which is very strong and neat. All forestry rims use a 2" sleeve with plug to protect the valve.

Using a wider wheel nearly always entails a non-central plate to ensure the tyre on its inside edge does not foul the bogie box. Due to the higher forces exerted with a

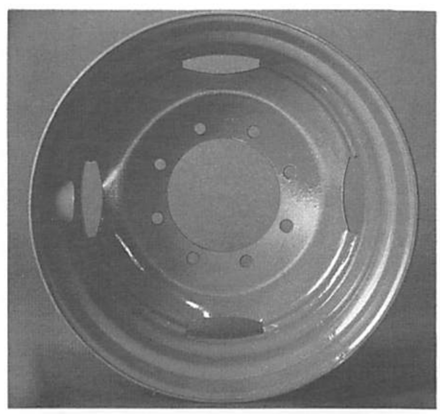


Fig 4. Wheel with standard drop centre rim.

large negative offset, it is often necessary to use a 15mm solid centre plate welded all round.

Current developments

Modern technology is towards tubeless with the basic advantages of:

- lower cost;
- less weight;
- less components to assemble.

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Editorial policy

Barry Sheppard
Hon Editor

Seeking out suitable copy, particularly from UK sources, has become harder over recent years due to the depression in agriculture and more recently in industry generally. There are far fewer people in the industry and many, as a result, are extremely overstretched in their jobs and just do not have the time to write up their work in a form to suit our wide audience. Also many agricultural engineers who were previously funded to carry out research, development and testing by government bodies are now involved in confidential, commercially funded contracts on which they cannot openly comment.

A recent decision which hopefully will stimulate our readership to come forward with more copy is that in future, two lead subjects will be featured in each issue. In this issue we are featuring Grassland Management and Environmental Control and Monitoring. This change will also help to focus our minds on who to approach for copy and will hopefully give a competitive edge to our readership. Can you afford to be left out of the issue which leads on your subject area?

In future issues we will be featuring:

1992	Summer	Forestry engineering: Tractor developments
	Autumn	Electronics: Livestock management
	Winter	Alternative energy: Quality control
1993	Spring	Crop storage: Pollution

Please keep the copy rolling in and do not leave it too late as we need your articles and papers for the forthcoming summer issue now!

Another decision taken by the panel – to accept more short papers or articles – will also hopefully stimulate copy. We will also continue to welcome longer more technical papers, be they externally refereed or internally edited and will continue to serve all specialisms within our Institution. Authors are asked, however, to bear in mind our now much more diverse audience when they are drafting their copy.

Finally, as you will have seen from the numbers of overseas papers we have featured over the last couple of years, we have many readers outside the UK. Also, in these days of increased European collaboration it is essential that we let our future partners know what we are doing and what is available in each others' countries. *The Agricultural Engineer* in its present form offers an excellent medium for this type of information transfer.

LETTERS

Comments welcome/ welcome comment

Sir,

I would like to congratulate the production team, particularly Mr Geoff Baldwin, on the improvement in both the presentation and the content of the magazine. The use of section headings to highlight the articles and the subtle changes in layout have made the magazine far more accessible to the reader. I wonder if the index could not be laid out with headings similar to those found in the text?

I realise that the amalgamation with *Soil and Water* took place over a year ago but post to Mozambique where I am stationed is rather slow and I was also behind on my reading.

I look forward to reading more useful technical articles in the new look magazine.

Martin Ede
CARE, Mozambique,
New York, USA 10016

The Hon Editor replies: A new layout for the contents page is introduced with this issue and we have been pleased to incorporate Martin Ede's helpful suggestion (*see also* Comment *page 1*).

continued from previous page

The problem that arises with tubeless tyres, however, is a subject we have already touched on. High power, excellent traction and low inflation pressure equals potential rim slippage. One answer is to increase the inflation pressure thus pressing the bead area of the tyre tighter against the rim, but this is a totally negative action for reasons we have already covered in depth. Working very closely in conjunction with the OSA engineers, Trelleborg have developed a rim incorporating a bead lock system. This has been extremely successful and these rims have now been released for general sale. To my knowledge, however, no machine has yet come into the UK with them fitted.

Current developments are 650/750 and 850mm wide on 775mm and 864mm rims in T404 tread pattern 14 and 16 ply steel belt. We have the moulds and load inflation pressure data but as yet have not manufactured any tyres.

So what is the limit in width, as the marketplace is demanding ever wider tyres? It is not a production problem as we yet know of, and certainly not a rim problem, as one can go on increasing its strength.

One of the major limitations without a doubt is the hub width on the machine which affects the offset. Hub widths must increase, as large negative offsets are not possible.

An excellent example of this is the original Braunett 578 which used a 500mm wide tyre on a standard rim. The 678 used a 600mm wide tyre with initially a standard rim. There were problems with the centre plate cracking around the bolt holes due to the larger negative offset and resultant increase in stress. This was overcome by using a thicker solid centre plate welded all round. Then, however, bogie box problems occurred so they had to be strengthened. If the hub width had been increased it is more than likely neither of these problems would have occurred.

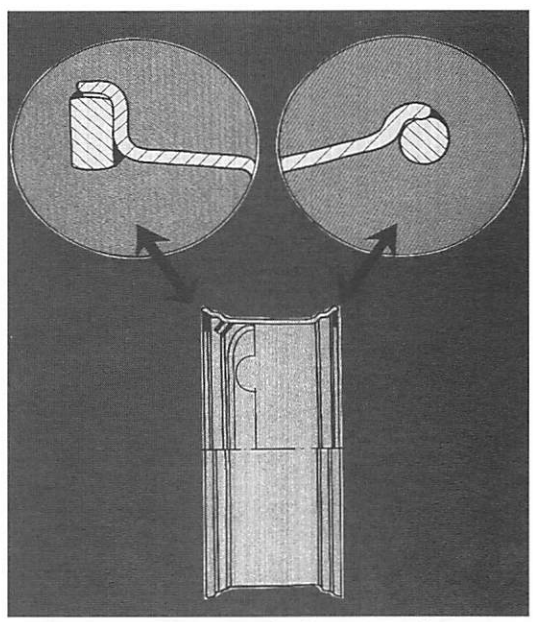

Fig 5. Rim reinforcement for forestry work.

In conclusion, in forestry as in agriculture, what is required from tyres is maximum traction, reliability and life with the minimum of compaction. The forestry situation can, however, be appreciably harsher with greater constraints and more expensive machinery. It is therefore essential that the correct tyres are chosen for the various forest machines and that down-time, due to tyre failure or indeed loss of traction is kept to a minimum.

Silage wilting technologies to reduce effluent production

Concern about the environmental problem associated with silage effluent has provided an incentive to agricultural engineers to develop technologies to produce high dry matter silage.

Malcolm McGechan here describes how 'mat making', a new technology currently at the experimental stage, offers the prospect of very fast drying rates, so that silage with a sufficiently high dry matter content not to create any effluent can be harvested on the same day as it is cut.

Silage effluent is the most serious watercourse pollutant produced by any industry, with a biological oxygen demand (BOD) 200 times that of untreated domestic sewage. It is also very corrosive, so special materials need to be used in the construction of clamps and effluent collection facilities. Recent changes in legislation have resulted in very large increases in fines imposed on farmers when pollution incidents occur.

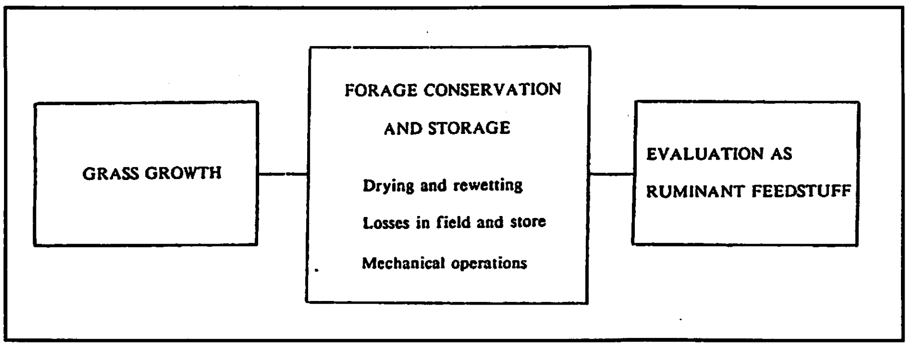

Fig 1. Principal components of forage conservation system model.

The quantity of effluent produced can be reduced substantially by wilting the crop before ensilage. If a dry matter content of 30% can be achieved, no effluent seepage occurs from clamp silage.

Over a number of years, there have been various developments in mower and mower conditioner technologies which were expected to increase wilting rates and make high dry matter contents easier to achieve. For various reasons, the recent trend has been towards less wilting, with lower average dry matter contents found in silages today than ten years ago.

In this article, the background to this disappointing trend, and the possibilities for further technological development are examined, in the light of experimental and modelling research at the Scottish Centre of Agricultural Engineering and elsewhere.

Wilting experiments in field and laboratory

A series of field experiments was carried out in which wilting rates were measured by a combination of weighing sections of swath at intervals and oven dry matter determination of grab samples (Lamond *et al*, 1988). Treatments considered include conditioning (with various conditioning devices) compared with no conditioning, wilting in swaths spread over the whole cut width compared with in windrows, and various turning or tedding policies compared to wilting in undisturbed swaths (Spencer *et al*, 1990).

Weather parameters were recorded during the experiments, so wilting rates could be related to parameters such as solar radiation, temperature, relative humidity, wind speed, or some combined parameter such as evaporation given by 'Penman's equation'. Parallel laboratory drying tests were also carried out to determine drying rates for the same grass material in thin layers under standard climatic conditions.

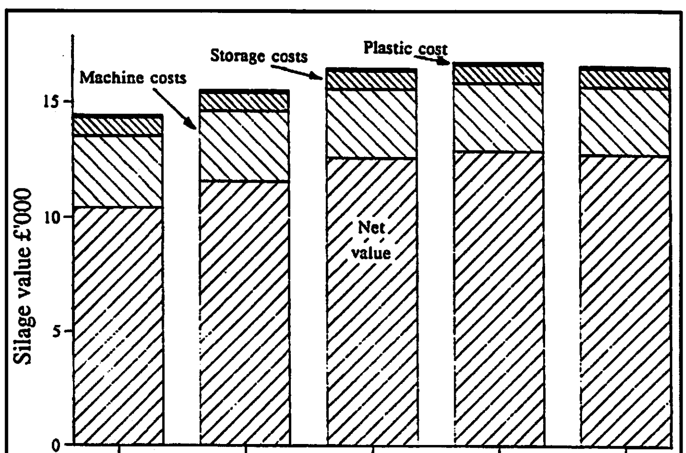

Fig 2. Effect of wilting on silage value (conservation area 40 ha, precision chop harvester)

Results showed that while conditioning increased drying rates compared to no conditioning by about 60% in laboratory thin layer tests, typical increases in the field were only about 20%. Under poor weather conditions, conditioning produced even lower increases in drying rates. However, spreading material increased drying rates by about 35% compared to wilting in windrows.

The combined effect of spreading and conditioning increased the drying rate by about 60% compared to wilting in a non-conditioned windrow. There were also small drying rate increases from a small number of tedding or turning treatments compared with leaving material undisturbed, but no further benefit for increasing the frequency of such treatments.

A model for the study of silage wilting technologies and policies

Modelling provides a means of studying the performance of complex agricultural systems and makes much more cost effective use of researchers' time than carrying out large numbers of field experiments. This is particularly so for weather dependant processes such as silage making, where simulated 'experiments' over long periods of years with a wide

Dr Malcolm McGechan is Head of the Operational Research Unit at the Scottish Centre of Agricultural Engineering, Penicuik.

range of system options can be carried out. Modelling also enables economic factors to be examined in parallel with complex physical processes. In this case, use was made of a weather driven 'whole system' model of the forage conservation process (Fig 1) (McGechan, 1990a).

In the model, grass growth is simulated in relation to daily temperature and solar radiation, for both the early season when seed heads are formed, and later on when leaf growth predominates. Simulation of wilting of swaths is based on data from the field experiments. Rewetting of swaths by rain and the drying of surface moisture (by a different process from the drying of tissue moisture) are also represented. Losses of valuable feed material are taken into account, including those which take place in the field by plant respiration, leaching by rain and mechanical disturbance, plus storage losses caused by oxidation, fermentation and effluent production. Field operations are simulated with typical workrates.

Using a typical ruminant ration formulation procedure, the 'gross value' of silage is calculated as the purchase price of bought feedstuffs which it can replace. This takes account of quantity and quality of silage produced, and the higher intake of high quality silage by animals. The 'net value' is then calculated by subtracting the production costs. The costing procedure computes hourly costs of machines from their initial purchase price. Costs of repairs, labour, fuel, additives and storage facilities are also considered.

For the study of wilting technologies and policies (McGechan, 1990b), a series of simulations was carried out using hourly weather records covering a ten year period for Prestwick Airport, in the main Scottish dairy farming area.

Results of modelling studies

Wilting options included direct cutting in a single operation with a flail harvester, direct cutting in two operations with a mower and a forage harvester, and wilting to target dry matter contents of 20, 25, 30 or 35%. Results showed substantial benefits from wilting compared to no wilting (Fig 2), with the optimum target dry matter content around 30%.

Mower options included both simple drum or disc mowers and mower conditioners with two alternative cutting widths. Results showed that mower conditioners produced silage of slightly higher gross value, but the higher cost of the mower conditioners compared to the simple mower roughly cancelled out any economic benefit.

The standard swath treatment followed the most common practice in the UK of leaving swaths undisturbed in the mower windrow until just before picking up. However, it is common in many continental European countries to spread and periodically ted swaths during wilting, so this practice was also considered. Results showed that tedding increased silage quality and gross value, but by an amount too small to justify the cost of the additional treatments.

If the grass was spread before harvesting, again there was a small increase in silage gross value, but insufficient to justify the cost of the additional spreading and rowing up operations. A worthwhile benefit was, however, shown from setting a mower conditioner to lay down a wide swath, then picking it up with a forage harvester fitted with ground driven 'gathering wheels', a low cost addition which can increase the take-in width to about 1.8m. In this option, the benefit of the fast drying rate from wilting in a swath spread almost over the full cutting widths was not cancelled out by the costs of extra operations.

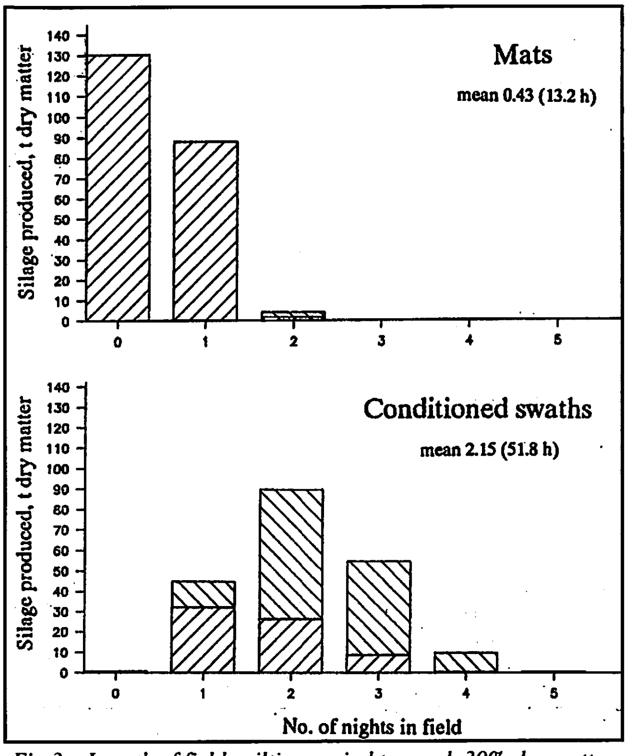

Fig 3. Length of field wilting period to reach 30% dry matter
rain free silage   rained on silage

Other options considered, not directly concerned with wilting but interacting with it, were the harvester type and setting, and the use of additives. Results showed benefits from using a precision chop harvester with a fairly long chop length setting (about 30mm) for medium or large farms. For small farms, the economics favoured a big bale system, with worthwhile benefits over systems based on flail or double chop harvesters.

The increase in forage quality resulting from the use of formic acid based additives was insufficient to justify their cost, even if used selectively.

Farmers' reluctance to wilt heavily...

There is clearly a large discrepancy between the findings of the modelling study which suggests economic benefits, not to mention environmental benefits, by wilting to about 30% dry matter content, and what happens in practice. A number of reasons can be put forward for this discrepancy.

Firstly, to achieve 30% dry matter requires material to remain in the field for about 48 hours under reasonable weather conditions, longer under poor conditions (Fig 3). Such long wilting times are perceived to be undesirable due to uncertainties about weather and losses which occur when wilting material is rewet by rain.

In fact, the model takes account of the weather uncertainty and losses, and still predicts benefits from such long wilt times. Waiting for weather suitable for wilting involves delaying silage making beyond the optimum stage of grass maturity, and this too is perceived as resulting in an unacceptable loss of quality, although again this has been taken into account in the model.

There is general agreement that animals' feed intake is higher (in terms of dry matter) with dryer silage, and this assumption is built into the model, but there are conflicting opinions amongst animal scientists about whether this is matched by an increase in animal performance.

Additives are perceived by some farmers as an alternative to wilting.

In recent years, any benefit from increased use of mower conditioners has been offset by a trend towards larger machines with greater cutting widths, which lay down a larger bulk of material into windrows of a width which remains at about 1.1m. There are even machines which lay a second windrow on top of the first, and experiments have shown that such large windrows dry extremely slowly. Increased use of contractors and increasing sizes of silage operations have both increased pressures to complete operations as quickly as possible, leaving little opportunity for heavy wilting.

... leads to need for yet more effluent storage capacity

The response of most farmers to the recently tightened pollution control regulations has been to upgrade their effluent collection and storage facilities, rather than to take measures to reduce the quantity of effluent produced.

In another ten years, perhaps in response to further legislative pressures about could

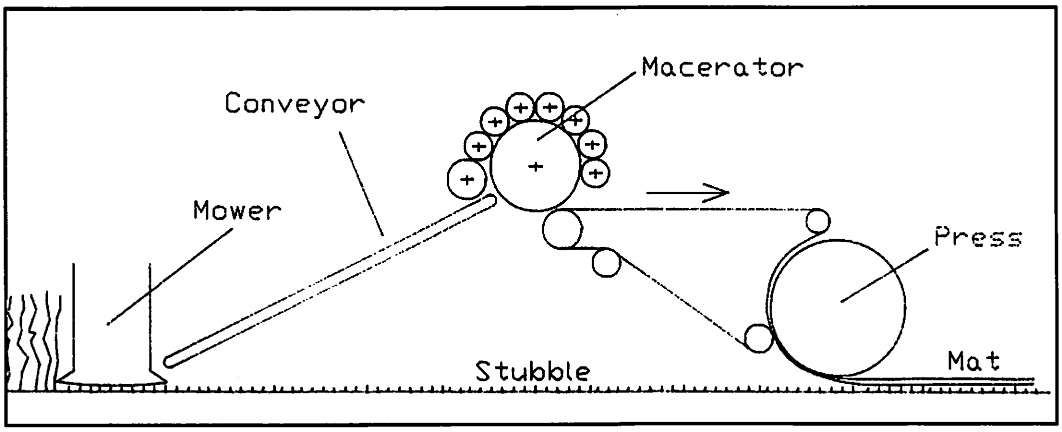

Fig 4. Prototype forage mat making machine (from Koegel et al, *1988).*

producing pollutants on farms, or perhaps when the effluent containing facilities currently being upgraded begin to deteriorate and need further upgrading, there may be a renewed interest in avoiding effluent production altogether.

Mat making as a new wilting technology

There is clearly a limit to the extent to which heavy wilting can be pushed using existing technology, either by increasing the effectiveness of conditioning, or by wilting in wider swaths, since relatively long field wilting periods will always be required. However, an alternative approach to rapid grass drying, based on a new 'mat making' technology, may offer the prospect of wilting to 30% dry matter content in a very short time.

The mat making system (Fig 4) consist of a set of knurled grinding rollers rotating at different surface speeds, between which the plant material is passed, where it is very severely macerated. Passing to a press consisting of pairs of rollers with smooth surfaces rotating at the same surface speed the material is then squeezed into a thin mat which is finally placed on the stubble. The system was originally developed in the USA for lucerne crops (Koegel, *et al*, 1988), but it has recently been tested in Canada, the Netherlands, Germany, Sweden and the UK on grass crops (Savoie and Beauregard 1991, Wandel and Bischoff 1990, Sundberg and Lundvall 1991).

Drying rates for matter material are at least twice as fast as for grass cut by a mower conditioner.

Wilting to 30 percent within the day; with possible improved digestibility

Simulations have been carried out using the forage conservation model with experimental drying rate parameters, to compare mat making with conventional technology (Savoie, *et al*, 1991). These have shown that for a West of Scotland site it should be possible to wilt silage to 30% dry matter content with very light overnight wilting or rain damage to swaths (Fig 3).

The economics of this system would compare favourably with a system based on a mower conditioner, despite the mat making mower having a higher capital cost and lower workrate (Fig 5). Such benefits arise because the expensive precision chop harvester in a conventional system can be replaced in the mat system by a low cost harvester which only picks up and carts the crop; because of the severe maceration at cutting time, no further chopping will be required to achieve a high crop density in the trailer and satisfactory fermentation.

Some evidence has emerged from North

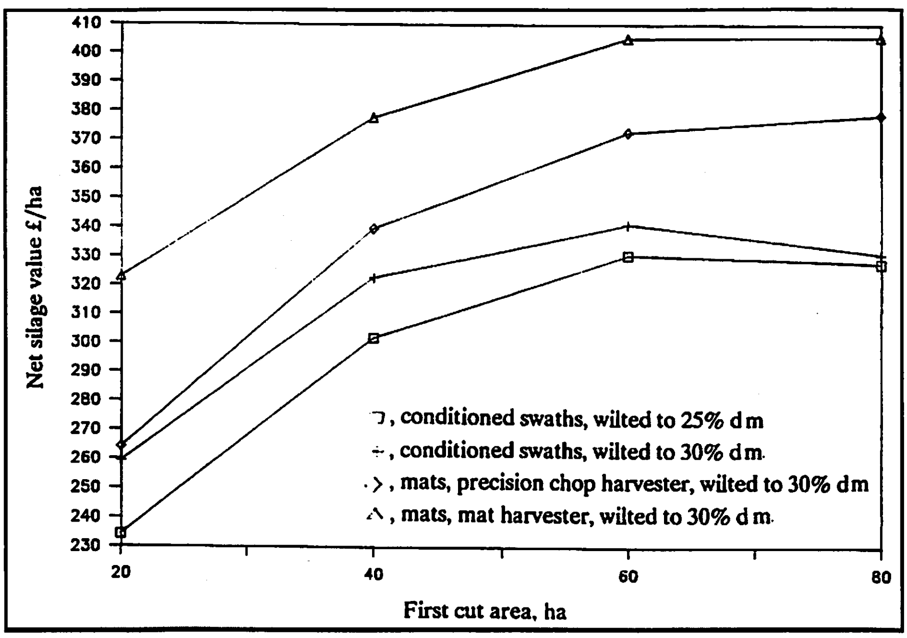

Fig 5. Silage net value for mat making system compared to conventional system with different farm sizes (dm = dry matter content).

American and European experimental work with both grass and lucerne crops (Koegel, *et al*, 1990, Wandel and Bischoff 1990), that the severe maceration associated with mat making breaks down some of the non-digestible components of the plants and increases the digestibility of the conserved crop. This suggests that the mat making may have a part to play in promoting more extensive and low input grass forage systems. Grass can be grown with little or no chemical fertiliser, and the yield loss made good by delaying cutting until a more mature stage. While the digestibility of such material would be unacceptably low in a conventional system, the mat making process should restore digestibility to a higher level. Testing the feasibility and economics of this process will be a future application of the simulation model, when more evidence becomes available about the extent to which digestibility is raised by the mat making process.

Conclusions

The more widespread use of mower conditioners, which give a small increase in drying rates compared with simple mowers, has been offset by other pressures which have resulted in silage being wilted less and more effluent being produced than ten years ago.

Research has shown that faster drying rates can be achieved by wilting in wide swaths than by using conditioners. Nevertheless, with conventional equipment, wilting periods of about two days will always be required to reach dry matter contents sufficiently high to avoid effluent seepage, and this practice is unlikely to achieve widespread acceptance amongst farmers, despite the economic and environmental benefits.

'Mat making', a new technology in which forage is very severely macerated then dried very rapidly in thin mats, could revolutionise attitudes to wilting,

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Greener and more profitable wheel-traffic systems for grassland

Jim Douglas

Wheel-induced damage to grassland in temperate regions (Fig 1) can have deleterious consequences for crop productivity, soil quality and utilisation of applied nutrients.

For example, in a survey of farms in Scotland, Soane (1987) reported that 29% of farmers perceived yield depressions attributable to over-compaction in grass grown for silage or hay. Similarly, from a review (Douglas 1992) of reports from a number of locations in northern Europe, a consistent pattern has emerged of reduced yields after a variety of wheel-traffic events and experimental treatments.

However, extrapolation of the findings from either short-term studies or from application of single sets of wheel-tracks on specific occasions, to the longer term on a farm field scale can be unreliable. Uncertainties associated with the criticality, duration and accumulation of traffic effects, together with the confounding interaction between weather factors, soil conditions and grass growth, contribute to the difficulty of predicting the overall economic or environmental outcome of the passage of tractor and implement wheels.

Studies to determine herbage yield reductions from traffic

A long-term, fully replicated traffic systems experiment, with an adjoining set of controlled compaction treatments, on a clay loam soil in Scotland has provided information on the response of grass-for-silage crops at realistic time and spatial scales.

The primary objectives of the work were to elucidate the extent and causes of herbage yield reductions by traffic, and to evaluate 'novel' systems of reduced ground pressure and zero traffic as practical methods of protecting grassland soil from the compactive forces beneath wheels.

Additional information was gained on the effects of traffic on the physical properties of the soil, the influence of rainfall on the relationship between soil conditions and herbage production, and the effect of soil compaction on the uptake of fertiliser-nitrogen.

For the traffic systems experiment (Douglas *et al*, 1992a) a reduced ground pressure system was assembled in which commercially available, larger-than-standard tyres were fitted to each machine and trailer (Fig 2) such that tyre/soil contact stresses were significantly smaller than for similar equipment fitted with conventional tyres (Fig 3).

In the zero traffic system, equipment was modified to operate from permanently positioned tracks at 2.8m wheel centres, enabling growth and management of the crop in 2.4m wide traffic-free beds.

Fig 1. Soil and sward damage after cutting and baling grass for silage in Scotland.

The crop of perennial ryegrass (var. Talbot) was established in autumn 1985 and, in subsequent years, was cut as for silage three times per annum.

For the controlled compaction experiments, conducted nearby on the same soil type (Douglas and Crawford, 1991 and 1992), grass was sown and managed in 2.4m wide plots using the aforementioned zero traffic equipment. Various compaction treatments were applied uniformly over plots by

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since material could be cut and harvested at high dry matter contents in one day with minimal risk of rain damage.

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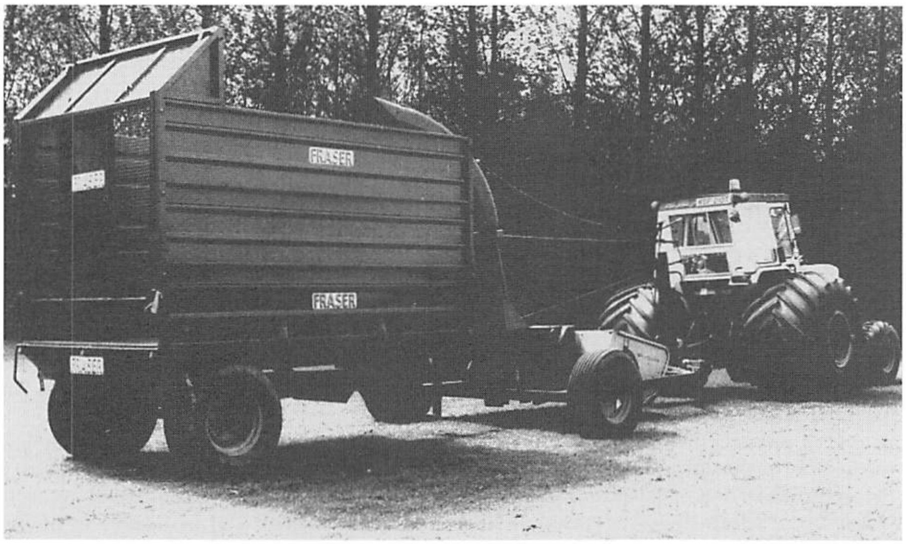

Fig 2. Reduced ground pressure forage harvesting equipment.

tractor wheels. In the second to fourth years of the compaction experiment, the rate of applied nitrogen was varied on zero, light and heavy compaction treatments.

Lower degree of saturation, hence better soil aeration

Throughout the period of the traffic systems comparison, the soil of the zero and reduced ground pressure systems was less dense than that in the conventional system. Average topsoil compaction on plots of both the conventional traffic and the reduced ground pressure traffic systems was largest at the end of the first harvest year, and thereafter, close to the soil surface, tended to decrease slightly (Fig 4).

Information on soil macropore attributes was obtained from an image analysis study. Images were obtained by photographing blocks impregnated with a resin/dye mixture. A quantification procedure showed that the volume of large pores in the upper 100mm was 2 to 2½ times greater in the soil of the novel traffic systems than in that of the conventional system (Koppi *et al*, 1992).

The main consequence of the larger pore volume in the soil under the novel systems was a lower degree of saturation, and therefore, better soil aeration during winter and the important spring growing period.

Nitrogen loss greater from compacted soil

A range of bulk densities, similar to the range of densities found in the systems experiment, was created for the controlled compaction study by passes of wheels that applied a tyre/soil contact stress of 40 or 100kPa for light and relatively heavy compaction respectively. As in the traffic systems comparison, the total porosity of the soil decreased as the amount of applied traffic was increased and the volume of the largest pores also was decreased significantly, especially by the relatively severe treatment.

Image analysis evaluations indicated that the growth of grass roots can have an ameliorative effect on the structure of initially dense topsoil, particularly if traffic-induced stresses are minimised subsequent to the initial compaction (Douglas *et al*, 1992b).

In addition to maintaining optimum conditions for crop growth, less compaction of the soil appeared also to reduce the amount of nitrogen lost through denitrification during wet periods. In studies of denitrification fluxes in 1989 and 1990, peak gaseous losses of N were 2 to 3 times larger from heavily compacted soil than from non-compacted soil.

Grass production down by a third under heavy compaction

The amount of herbage dry matter produced under the two novel traffic systems was consistently larger than that yielded under the conventional system (Fig 5).

The overall yield advantage was attributable primarily to large differences at first cut: on average, there was a first-cut yield benefit of 30% from omitting or reducing the compactive forces of the field equipment. However, note that the zero traffic yields are those obtained from the area alone; when the area of the uncropped wheeltracks was taken into account the true zero traffic system yield was reduced by 17%.

Yield results from the controlled compaction experiment generally confirmed those from the systems experiment. Moreover, it was demonstrated that the presence of soil compaction in the relatively wet conditions of springtime was particularly damaging to the subsequent growth of the grass (Fig 6).

Heavy traffic applied at the time of harvesting the first cut in the first year resulted in yield reductions of 34 and 26% at first cut in the following year relative to zero and light compaction treatments respectively. Herbage production at first cut in the second year was related closely to the amount of traffic (tyre/soil contact stress times number of wheel passes) imposed prior to that primary growth period.

In each of the three years when N application rate was varied in the controlled compaction experiment, response to fertiliser nitrogen for first cut was impaired by compaction (Fig 7). Following some natural amelioration of the initially heavily compacted soil by root growth and earthworm activity (Douglas *et al* 1992b,c) crop performance improved in that treatment in successive years relative to that in the non-compacted treatment.

Nitrogen use – greater uptake with less compaction

As with yield, the effect of over-compaction on nitrogen use was most pronounced at the first cut in each season.

In both the systems comparison and the compaction experiments, the calculated seasonal offtake of nitrogen was consistently larger when the degree of soil compaction was relatively small. This was a consequence of heavier dry matter yields and higher concentration of nitrogen in the herbage.

In the systems experiment, over five years, the average recovery of the applied fertiliser-nitrogen (300 kg ha^{-1} yr) was 75 and 73% in the crops of the zero and reduced ground pressure systems respectively, compared with 57% in that of the conventional traffic system.

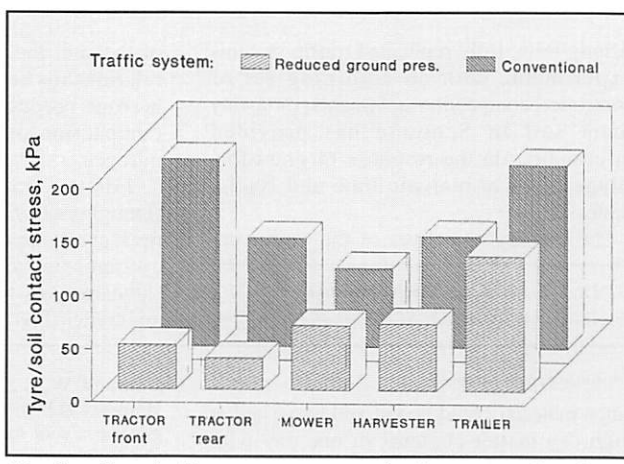

Fig 3. Tyre/soil contact stresses in the conventional and reduced ground pressure traffic systems.

Practical implementation and economic considerations

In terms of maintaining soil structural conditions likely to be most suitable for grass growth on relatively wet soils in areas where spring and summer rainfall markedly exceeds potential evapotranspiration, a zero traffic system would be the most effective of those tested.

However, in terms of herbage production and utilisation of applied nitrogen, the reduced ground pressure and zero traffic systems were equally successful.

The major limitations of the zero traffic system are the portion of uncropped land in the permanently positioned wheeltracks (17% for that based on 2.8m wheel centre as described above) and the need for manufacture or modification of wide-span equipment.

Although the gantries that are available for a number of operations in arable cropping (Chamen, *et al*, 1992) are sufficiently wide to reduce the wheeltrack area to a much smaller proportion (3% for a 12m gantry), equipment for cutting and lifting the crop has yet to be developed.

On the other hand, a reduced ground pressure traffic system can be adopted more readily. Larger-than-standard tyres can be fitted to most forage harvesting equipment, perhaps with some modifications; an in-line forager is desirable if extra-wide tyres are used on the tractor.

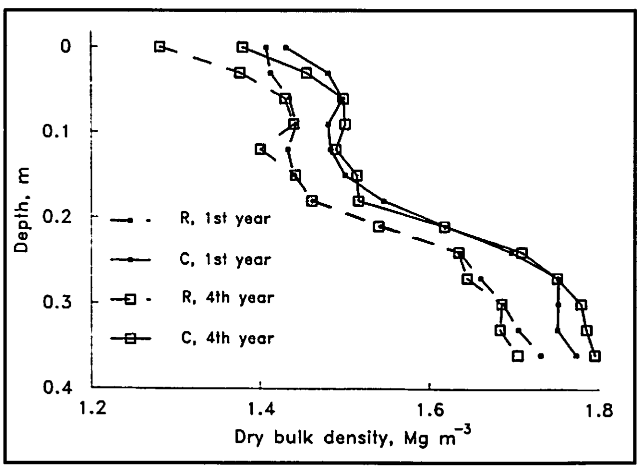

Fig 4. Soil bulk density profiles in the reduced ground pressure (R) and conventional (C) systems in the first and fourth years of the experiment.

The cost of a full replacement set of tyres to provide low tyre/soil contact stresses from the tractor, mower, forager and trailer could be as much as £5000. However, taking a nominal value for silage of £80 per tonne dry matter, and the average annual reduced ground pressure yield advantage of 1.6t ha^{-1}, the outlay would be recouped in one year after harvesting 40ha of grass.

Benefits of minimising compaction

- Minimising or eliminating compaction in grassland promotes improved crop growth and increased efficiency of nitrogen use. These benefits accrue from the larger volume of air-filled macropores present in relatively non-compact soil compared with the low porosity structure of over-compacted land.
- Good conditions for grass growth, closer to optimum than those found to exist after conventional field traffic, can be maintained by use of appropriate novel traffic systems. Currently, a system comprising equipment fitted with tyres that exert relatively low tyre/soil contact stresses is a more workable alternative than a zero traffic system.
- Adoption of traffic systems that are less damaging to the soil than conventional traffic may provide additional benefits from maintaining porous soil structure, such as reduced potential for run-off of surface water and dissolved chemicals and volatilisation of nitrogen compounds, and easier soil preparation for subsequent reseeding.

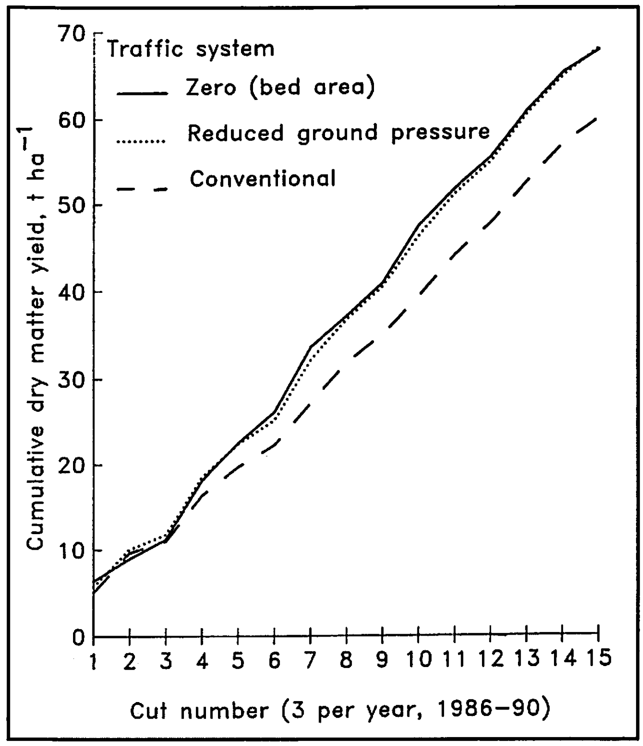

Fig 5. Cumulative dry matter yield in zero traffic beds and the reduced ground pressure and conventional systems, years 1 to 5.

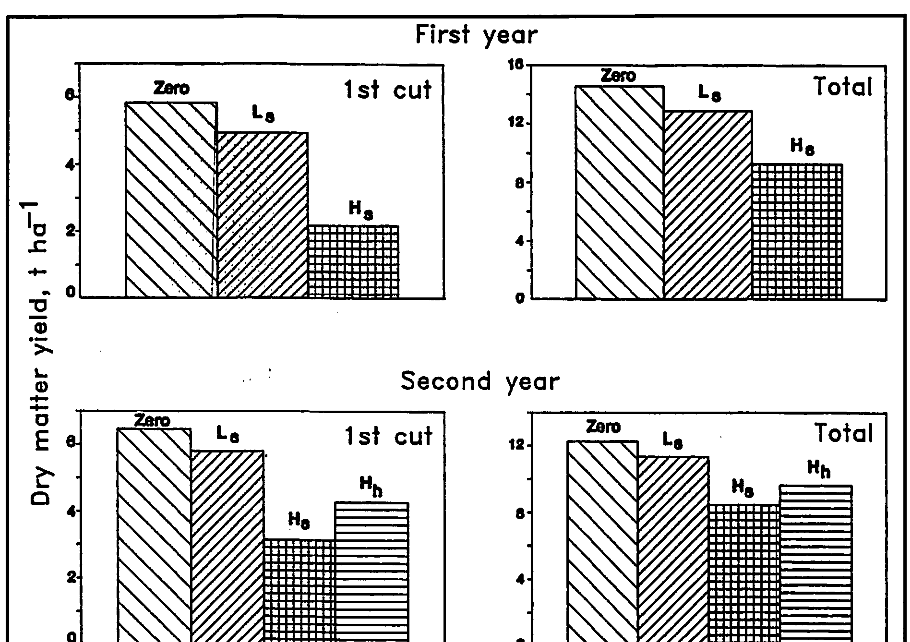

Fig 6. Herbage dry matter yields after zero, light (L) and relatively heavy (H) compaction treatments created in spring (s) or at first cut harvest (h).

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Agricultural Machinery Law

Our thanks to the bi-monthly publication, *Farm and Garden Machinery Law* for allowing us to reprint the following abstracts:

The Tractor Noise Directive – 77/311/EC : interim agreement of 1977 never followed up

Back in 1977 the European Community managed to agree on the acceptable level of noise for agricultural and forestry tractors. There was, no doubt, disagreement, debate and compromise but eventually it was agreed that no Member State would refuse type approval on the grounds of 'driver-perceived noise' lower than 90dB for a laden tractor (86dB unladen) submitted with an enclosed tractor-cab and 96dB, laden, (92dB unladen) for a tractor without a cab (or with all doors and windows open).

It was also agreed that for a transitional period an extra 6dB should be added to these test limits to allow manufacturing companies time to adjust their methods of production to the agreed level of driver-perceived noise.

The Directive states that the dispensation was to be withdrawn 'on a date to be fixed before 1 October 1981'.

The problem is that a date for ending the dispensation was not fixed either before that date or after. In 1984 an attempt was made to agree on a date but no conclusion was reached.

Recently six EEC Approvals issued by the UK for tractors within the dispensation levels were subsequently withdrawn on the grounds that the Ministry of Agriculture felt that sufficient time had elapsed for industry to make the adjustments and that it was open to a Member State to unilaterally implement the agreed levels of DPN. It would not have been the intention of the Council back in 1977 to extend the dispensation for as long as fourteen years.

This action was strongly contested by the AEA acting on behalf of the industry. As a result, the Ministry have compromised by deciding to confine their resistance to notifying other Member States by letter that a tractor submitted for type approval had failed to meet the lower noise levels.

The point has now been taken up by CEMA, the industry's European organisation, because it has obvious implications for the import into the UK of tractors given type approval within the scope of the dispensation elsewhere in the Community. The price effect of satisfying the higher DPN has not been fully understood and the wider use of air conditioning in cabs since 1977 makes the value of a noise test with all doors and windows open somewhat questionable. It is hoped that there will now be an opportunity to review the original decision.

Mobile Machinery Directive published : definitive wording

The definitive wording for the Directive dealing with the safety provisions for mobile machinery was published in the Official Journal on 22 July 1991. Directive 91/368/EEC has been framed as an amendment to the main machinery directive – 89/392/EEC. (See FGML Vol 1 No 1 for the background).

Trailer badly loaded : not necessarily 'unsuitable'

A trailer designed for the purpose of carrying goods and which was suitable for that purpose, did not become 'unsuitable' within the meaning of the Road Vehicle (Construction and Use) Regulations 1986, merely because it had been badly loaded by the user.

Road Vehicle (Construction and Use) Regulations 1986
SI 1986/1078 Reg 100(3)
Hollis Bros v Bailey (1968) 1 WLR 633
British Road Services v Owen (1971) All ER 999
Young v DPP (1991) Times 30 April.

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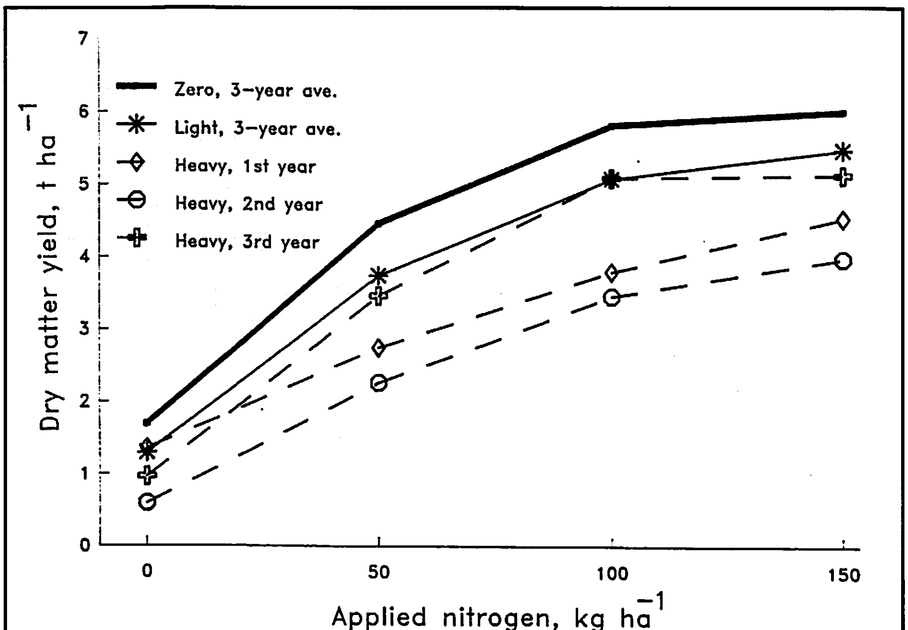

Fig 7. Herbage yield response to applied nitrogen averaged over three years in the zero and light compaction treatments and in each year in the heavy compaction treatment.

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