The Agricultural Engineer

Incorporating **Soil** and water

Volume 49 Number 2 Summer 1994

A day in the life of ...

... the new Institution President

A Ferguson First

Display at the Royal Norfolk Show

It's almost 110 years since Harry Ferguson was born (November 1884) and that has been a good enough excuse for the Royal Norfolk Agricultural Association , in conjunction with the Norfolk Farm Machinery Club and sponsored by Midland Bank, to lay on a display of this great man's work.

To our profession, Harry Ferguson is a 'tractor man', and quite rightly too, but tractors were only part of this man's interests. On show will be other exhibits of his fertile mind — planes, racing cars and road-going vehicles too (particularly those employing four-wheel drive) as well as a representative range of 'his' tractors.

The exhibition will be part of the Royal Norfolk Show. Show Director, Gavin Alston, believes this to be the first such display of every aspect of Harry Ferguson's work. If you're near Norwich on those days this tribute to him will be well worth a visit.

The Royal Norfolk Show
Norwich, Norfolk
29 and 30 June 1994

The Agricultural Engineer

Incorporating **Soil** and water

Volume 49 No.2, Summer 1994

Journal and Proceedings

THE AGRICULTURAL ENGINEER incorporating Soil & Water is published quarterly by the Institution of Agricultural Engineers, West End Road, Silsoe, Bedford MK45 4DU. Tel: (0525) 861096.

Price £10.50 per copy, annual subscription £41 (post free in UK).

Front cover: Two aspects of Professor Dick Godwin's professional activities in soil and water management.

Regular Features

CONTENTS

COMMENT

The Annual Convention held this year on 17 May at Harper Adams College was widely thought a great success. It continued the policy of holding low-cost, action-packed, single day conventions, and a full report will appear in the next issue of The Agricultural Engineer.

At the AGM in the morning, the new President, Dick Godwin, was elected. The Earl of Selborne gave the keynote address and Cecil Currin from the USDA Soil Conservation Service led the plenary session. There were eleven technical sessions in the afternoon, two site visits and a light-hearted student competition.

In the evening, the new President, Dick Godwin, presented an Honorary Fellowship to John Matthews, an Award of Merit to Dan Hettiaratchi, and a Branch Meritorious Award to Richard Barrowman. The Johnson New Holland Award was presented to a team from Harper Adams College, the Douglas Bomford Meeting Award to Toby Mottram, and the Branch Recruitment Award to Wrekin Branch.

On behalf of the Institution, the President was delighted to receive from Cecil Currin a US flag which had been flown over the Capital on 5 April 1994 in honour of the Institution.

It was a busy, well attended and successful day, which gave an opportunity for old friends to meet again as well as to keep up to date technically. An important development was the re-instatement of the Recruitment Panel under the Chairmanship of Brian May, President 1984-86. He is already working on the task and producing novel ideas.

One of the key areas in which members derive benefit from the Institution is in the transfer of information. The following conferences are being planned for this year:

1 September	Forestry Engineering Group	Annual conference	Newton Rigg College
25 October	Machinery Management Group	Sprayers	Silsoe College
November	Soil and Water Management Group	Soil sustainability	Silsoe College

Details of further conferences to be held in 1995 will be given in our next issue.

ISSN 0308-5732

President:
Eur Ing Prof R. J. Godwin BSc MS CEng FIAgrE MASE

Secretary:
Michael Hurst BSc MBA CEng MIEE MIMgt

The Institution of Agricultural Engineers

Round baler sales

The Claas Rollant round baler with Rollatex net wrapping facility.

Baler sales are also following the trend towards higher output with one in five of Claas Rollants being of the Roto Cut type.

Introduced last season, the Rollant baler has a chopping mechanism to increase bale weights by up to 30 per cent. This, in turn, reduces handling, wrapping and transport costs.

Claas also reports that 80% of all Rollant balers sold are now equipped with the Rollatex net wrapping facility, compared with 60% two years ago.

Claas UK Ltd, Bury St Edmunds, (Tel: 0284 763100, Fax: 0284 769839)

Renault Agriculture forges links with major competitors

Bruno Morange, President and Director-General of Renault Agriculture, has announced important partnership projects with John Deere and Massey-Ferguson.

The John Deere agreement concerns the supply of John Deere engines for part of the range of Renault tractors. Renault will also make tractors fitted with John Deere engines for John Deere.

A technical and manufacturing partnership has been created with Massey-Ferguson in which each has a 50% share. This will concentrate on the design and development of mechanical, hydraulic and electronic equipment. It will also provide for the manufacture of certain common mechanical components.

The agreement also embraces an Economic Group (GIE) that will buy all components, except engines, bodywork and cabs, required by the two companies for their respective tractor production.

Quality Control obviates need for customer inspection

Rubbernek Fittings Ltd, manufacturers of specialist hydraulic tube fittings, has recently moved its full commercial and production facilities to new premises located at Walsall Wood in the West Midlands. The company was formerly located in Sutton Coldfield, and despite doubling in size at this location, it had reached a point where further expansion was impossible.

The RFL company was formed in 1965 with an American parent organisation, but became a wholly owned British company in 1986 after a management buy-out.

BS5750 accreditation is anticipated before the end of this year, with RFL now able to offer a better service based upon its greatly enhanced production facilities, coupled to more efficient planning and quality control.

RFL customers are mainly major OEM companies operating in the field of international construction and agricultural equipment together with diesel engines. Fittings are manufactured to various SAE, DIN and BS standards, mainly from steel or brass with some stainless steel components.

Further information is available free on request to: Rubbernek Fittings Ltd, Hall Lane, Walsall Wood, Walsall, West Midlands WS9 9AP (Tel: 0543 453533; Fax: 0543 453531).

Case IH returns to the Royal Show

J I Case Europe and the Royal Agricultural Society of England (RASE) announce that Case IH is returning to the Royal Show in both 1994 and 1995.

According to Jeremy Lamb, Director, Sales and Marketing UK, the decision to return was taken following the success enjoyed by the company at the recent Royal Smithfield Show. UK farming has also experienced a better than expected year in 1993. This, coupled with the new strategy being developed by the RASE to provide the farming community with a prestigious business event were instrumental in making the commitment for the next two years.

The company will exhibit on a prime site next to the Grand Ring at Stoneleigh reinforcing Case IH's objective of maintaining and strengthening its position as a leading manufacturer in the worldwide agricultural industry.

Kemper range available in UK

Anker Machinery Co Ltd has negotiated with Kemper to import and market the Kemper range of machinery and spare parts through distributors and dealers.

The Champion 3000 rotary crop header was awarded the 1993 Gold medal by the RASE for its contribution to the mechanisation of farming. The rotary mowing system enables the header, that fits self-propelled forage harvesters, to cut maize, whole crop silage and even willow for renewable energy resources.

Anker Machinery Co Ltd is at 60 The Avenue, Southampton SO17 1BD (Tel: 0703 233193; Fax: 0703-339272).

UK tractor registrations up 33% in 1993

UK registrations of agricultural tractors (over 40 hp) rose 33% in 1993 to 17,899 units. This represents a strong recovery from the lowest ever level of registrations recorded in 1992.

The need to replace machines had been evident for some years and improved farm incomes plus better (short-term) prospects for British farming allowed a high level of replacement during the year.

Investment was also encouraged by the availability of accelerated first year capital allowances available for the 12 months up to the end of October 1993.

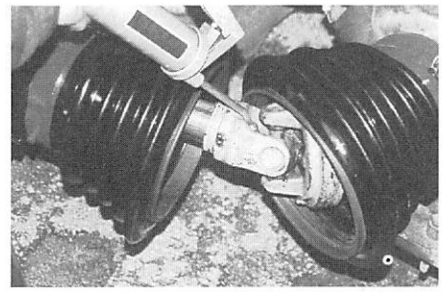
Year	Units registered
1985	23701
1986	17667
1987	18285
1988	21068
1989	18642
1990	16885
1991	14315
1992	13454
1993	17899

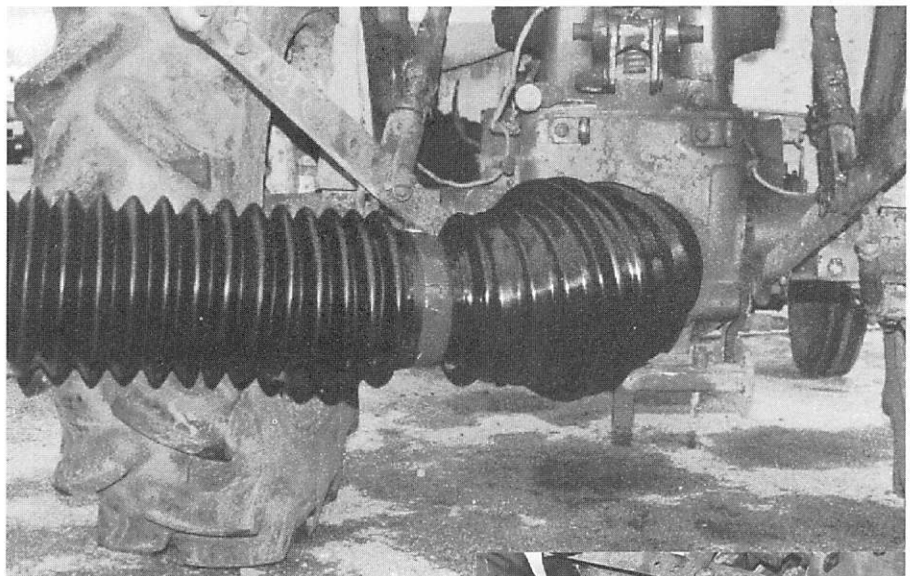
Demand for other machinery was also firm and the total spend by farmers on machines other than tractors is estimated to have increased some 15% over 1992 levels.

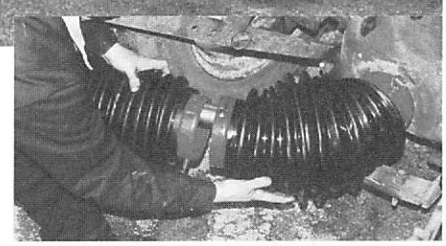
The prospects for 1994 appear reasonable and orders books are presently satisfactory but it is unlikely that the sales of tractors will reach 1993 levels as some sales will have been brought forward for tax reasons.

New angle on PTO guards

The patented Totalguard system of bellows type enclosure for PTO shafts has been expanded to include a wide angle joint cover. This is claimed to be the only wide angle joint cover to totally enclose all moving parts.







Two convoluted, tapered covers form the enclosure. These are connected by lockable, high impact polyacetal rings, allowing access to grease points on the shaft but ensuring total enclosure during operation.

Spaldings, Lincoln. Tel: 0522 500600.

The Caledonian Timber-Trak carries up to 10 t of timber loaded by a 6.5m reach Patu crane.

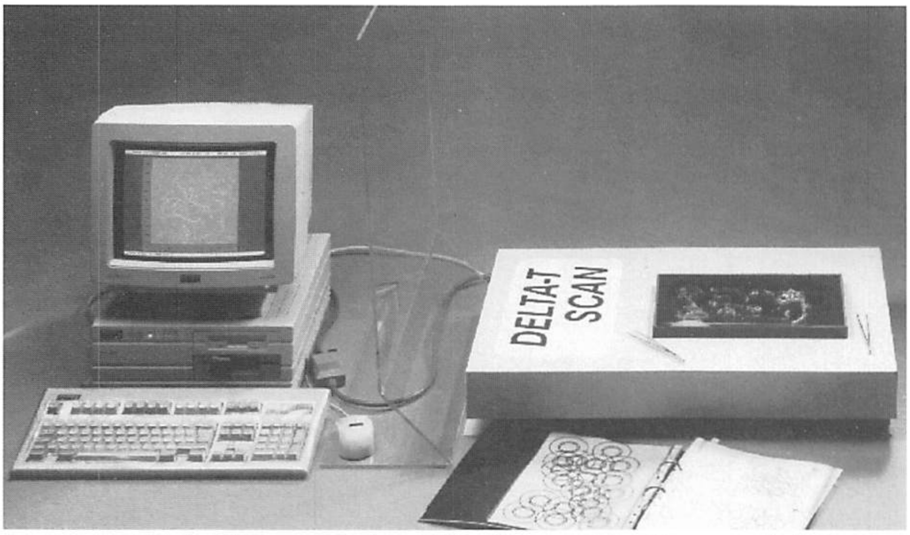
Hybrid forwarder

The Caledonian Timber-Trak is claimed to provide a cost effective method of extracting sawn timber for contractors and estates. A standard tractor minus front axle forms the front end. This is linked via a pivot assembly and steering rams to a Patu timber trailer which is complete with hydraulic crane. A PTO driven hydraulic pump powers the trailer wheels and the crane. The resulting unit is around one metre shorter than the equivalent tractor/trailer combination, while traction and manoeuvrability are said to be much better.

Several trailer and crane sizes are offered, and the customer can opt for a new tractor or have an existing one converted. The cost is claimed to be half that of a purpose built machine.

Caledonian Forestry Services, Tullibardine, Perthshire. Tel: 0764 663798.

Image analysis scanner



A customised Flatbed Scanner linked to a PC offers a variety of image analysis functions including object count, area measurement and particle size distributions.

Intended primarily for root analyses, Delta-T SCAN offers a fast and easy method of measuring root tip count, root length and diameter distributions. Other suggested uses include examining soil structure and measuring spray droplet numbers and size distributions. No specific calibration is required, and the device is claimed to provide superior resolution over a much larger area than video based systems.

Delta-T Devices Ltd, Cambridge. Tel: 0638 742922.

Massey-Ferguson to build tractors for Iseki

Massey-Ferguson's Coventry factory has started manufacturing tractors for Japanese producer Iseki in an agreement that could add £5 million annually to the company's export earnings. M-F's Beauvais plant in France announced a similar agreement last year for the supply of high horsepower tractors to Iseki.

Under both agreements, the tractors are being supplied in Iseki's own livery of crystal blue for sale in Japan by Iseki, in association with Mitsubishi Corporation, M-F's distributor for the past 40 years.

The Coventry-made models are designated the Big T 70 at 66 DIN hp, the Big T 80 at 79 DIN hp and the Big T 98 at 98 DIN hp, and all three will be supplied in cab and non-cab versions. Incorporating M-F's highly successful 12 forward 12 reverse side shift shuttle transmission, creeper gears, shiftable pto and air-conditioning, the tractors have been specifically designed for the Japanese market.

The factory expects to ship about 350 of the Iseki models annually.

Prime Minister presents International Quality Award to Perkins

The Prime Minister's visit to the Perkins headquarters in Peterborough. Around the engine are: (l to r) Minister of Health Rt Hon Dr Brian Mawhinney MP; Tony Gilroy, Perkins Group Chief Executive; Rt Hon John Major MP and Myles Coleman, Perkins General Manager Manufacturing.

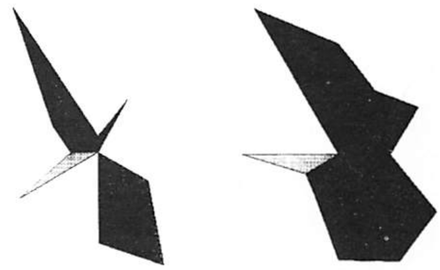
Every one of the five separate business units that comprise the Perkins Group of Companies – a world leader in the manufacture of diesel engines – has been awarded the internationally recognised quality standard — ISO 9000 Series.

Managing directors of the five Perkins companies received the prestigious quality award from Prime Minister the Rt. Hon. John Major, at a special presentation ceremony at Perkins headquarters in Peterborough on Friday January 7th. Before presenting the certificates, the Prime Minister toured the plant meeting some of the people responsible for manufacturing engines.

Receiving these Quality Awards, Perkins Group Chief Executive, Tony Gilroy declared: "ISO 9000 recognition demonstrates that we have the processes, procedures and controls to deliver to world competitive levels of customer satisfaction and is a further step in our desire for continuous improvement."

Perkins, founded in 1932, has produced over 13 million engines and around five million are still in service. Today more than 300,000 diesel engines are produced each year in two UK manufacturing plants and in overseas manufacturing locations in 10 countries.

Sniff out the rotters

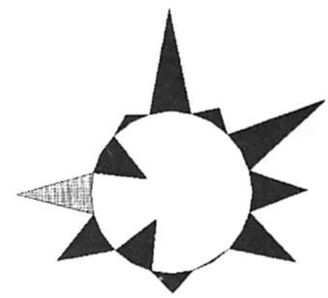


The Neotronics Olfactory Sensing Equipment (NOSE) is the result of years of work at Warwick University by Dr George Dodd.

Using an array of conducting polymer sensors, the vapour from a product or process is characterised and then compared to a known reference pattern. Variations from the reference may signal a quality problem in, for example, the food, drink and perfumery industries.

NOSE includes software which can simply trigger a warning when preset tolerance limits are exceeded, or it can visually display the results as a polar or difference plot.

At left; The Neotronic Olfactory Sensing Equipment (NOSE). At right (clockwise): Polar plot for a white wine; polar plot for a champagne; plot showing the difference between the white wine and the champagne.



The difference plot with no deviation appears as a plain circle.

Specific sensor arrays can be customised to individual requirements. It is anticipated that, by replacing testing panels, NOSE will give a considerable saving in quality control costs.

Neotronics Ltd, Bishop's Stortford, Tel: 0279 870182.

Lemon aid for industry

The phasing out of ozone depleting chlorinated solvents has led to the introduction of Lemsolv, an industrial degreaser based on a distilled lemon extract called D'limonene.

Lemsolv is blended with surfactants and rust inhibitors to produce a range of cleaners, from heavy degreasing to printed circuit board cleaning and adhesive removal for the plastics industry. All are claimed to be non-carcinogenic, non-ozone depleting and biodegradable. Fume extraction is not required, unless staff object to the smell of freshly squeezed lemons!

Environmental Solutions, West Bromwich. Tel: 021 525 7783.

High transmittance double glazing for greenhouses

At the 'Plantec' International horticultural fair in Frankfurt last autumn, the 1993 award for technical advances in horticulture went to Plexiglass SP Alltop.

Plexiglass is a multi-skin sheet with similar high light transmittance as single glazing, but with the energy saving advantages of double glazing. Used predominantly for greenhouses and private houses, a large web spacing (64 mm) is combined with 'Alltop' coating inside and out. The special coating causes rainwater and condensation to flow off in a continuous film, giving better transparency and cleaning during rainfall.

The increase in light and UV transmission compared to conventional double glazed sheets is claimed to promote plant growth.

Roehm Ltd, Milton Keynes, Tel: 0908 274414.

LGP implement tyres

New standards in flotation and minimal soil compaction are claimed for a range of 22.5 inch wide tyres introduced by Vredestein.

Intended for trailers, slurry tankers and harvest machinery, the Flotation + tyres use the latest flexible nylon carcass construction to provide a large contact area. Combined with a self cleaning tread design, the tyres offer minimal compaction and a low rolling resistance. Three low profile sizes available: 550/60-22.5, 600/55-22.5, and 700/45-22.5.

Vredestein (UK) Ltd, Wellingborough, Northants, Tel: 0933 677770.

Dick Godwin FIAgrE
President

Annual Convention 1994

President's Inaugural Address

Expanding Horizons

In his inaugural address in 1992, Immediate Past President Brian Finney outlined the challenges and threats to the Institution and the part that we all as members must play regarding Professional Status, Learned Society and Discussion functions. His comments are just as relevant today.

However, the last two years have seen a number of significant changes within the Institution — namely:

- **a better overall financial position**
- **an improved financial and membership computer support system**
- **a greater attendance at the Annual Conventions**
- **strengthening roles of the Specialist Groups and the formation of the Amenity and Ecological Engineering Specialist Group**
- **a better understanding of member needs**
- **fewer concerns from the threats of being squeezed by the larger Institutions**
- **an increase in student membership and increased student centred activities**
- **a reduction in secretariat staffing level whilst maintaining a high standard**
- **the only real downside – a small reduction in overall membership**

Our future challenges

Members of the IAgrE are probably engaged in a wider range of professional activities than ever before, which, while not only challenging for the individual, is also a challenge for the Council and Executive to ensure that the Institution meets the members' needs.

The current membership is not only involved in the application of mechanical engineering principles to equipment design, manufacture and product support, but also in an ever-increasing dependence upon electronics and computing skills. This is well illustrated by the work at all levels in precision farming (or site-specific agriculture) which is naturally linked to the electronic control functions fitted to the tractor. The development of the software to enable the correct decisions to be made by the farmer/advisor is no insignificant task and requires a sound knowledge of soils, crops and machine systems.

Environmental pressures and land management

The environmental pressures on agriculture are forcing changes in weed control methods whether by reduced levels of agrochemical application, alternative mechanical methods or a combination of both.

The solutions developed by agricultural engineers for land application of wastes from farm, municipalities or landfill sites are finding environmental acceptance but much work is still to be conducted before the ecological impact of the systems is fully understood. Engineers are now becoming involved with the chemistry and biochemistry of the systems as well as the mechanical and agronomic requirements.

The effects of change in the CAP and wider environmental issues have demanded a completely different set of criteria for land management and hence agricultural engineers are attempting to recreate semi-natural habitats for both flora and fauna. As a result, drainage and sub-irrigation systems are now designed to control water tables at levels different from production agriculture optima, and the influence of alternative cutting regimes on resulting plant communities is being studied.

Remote sensing and modelling

Agricultural engineers have developed the remote sensing methods for validating agricultural inventories, UK and EC crop yield estimates and the strategic management of the Common Agricultural Policy. Others with database management and expert system skills are currently attempting to model the most likely semi-natural plant communities, for

Paper presented by the President, Professor R J Godwin at the Annual Convention of the Institution, held at Harper Adams Agricultural College, 17 May 1994.

given soil, climatic and alternative management inputs, arising from set-aside.

Forestry engineering and crop diversification

The challenges in the forests are no less than those in the fields, and while coppice management is not new, finding methods and machines within the current value of the product presents a challenge. In other areas, forest engineering is well advanced. Vehicle design and advanced tree harvesting equipment, including the use of telemetry and global positioning systems, are examples.

Alternative industrial crops for fibre and fuel are vital for the future wealth of rural areas, as has been seen by the uptake of linseed and the change in policy with respect to the use of straw as an energy source in power stations. It is far better to burn it somewhere useful than create an environmental hazard through in-field straw burning.

The developing world – the food storage problem

In the developing world, food storage is still a very significant problem and will become even more so if the predictions by Spedding at the IAgrE Convention in 1992 are correct. In these he argued that, based upon world population growth statistics, the world will need as much food in the next 30 years as it has produced since the history of man.

Shift in food production regions

More recent analysis by Carruthers 1993 suggests that, as manufacturing moves towards the developing world, principally the Asia- Pacific region (as a result of lower labour charges and the greater speed of technological flow) so food production will move to the temperate regions. This is not some far-off long term possibility but could well start to be realised within the next decade.

Whilst Carruthers forecasts the demise of tropical agriculture as we know it, those engaged in smaller scale, high-production-cost agriculture in temperate zones had best beware.

The challenge to agriculture is to ensure that production is widely based throughout the world. The strategies of politicians and planners must take these long term scenarios into account.

The opportunities

It would be foolish to try to predict exactly the future challenges, but it would be reasonable to assume that the opportunities for engineering linked to the land based industries will have strong associations with changes and development in:

- Electronics and Computing
- Environmental management
- Energy sources and
- Economics

Conclusion

There is a common message to both individual members and the Institution as a corporate body, which is that in order to survive (and hopefully prosper) we have to be keen, flexible and affordable in the whole area associated with engineering for the land based industries, and actively seek the new opportunities.

I ask you as members, who have a corporate stake in the Institution, to help:

- develop the Journal and Publications of the Institution. – *why not agree to write something?*
- establish a programme of Specialist Conferences. – *why not make suggestions, especially in the developing areas, and help organise such a conference?*
- increase participation in Branch meetings, Specialist Groups and Annual Conventions. – *why not attend?*
- recruit new members. We need to stop the downward drift. Currently this is the major threat to the survival of the Institution. – *why not recruit a new member?*

We can only attract and keep new members if we have:

- the right Journal and Publication
- an exciting series of Specialist conferences
- active participation in Branch meetings, Specialist Groups and Annual Conventions.

It is no use for us to say we are expanding our horizons if we are not seen to be active in the new areas, hopefully from which we can attract new members. Can I challenge and empower all of the membership to work towards the above objectives and ask you all to consider:–

" Ask not what the IAgrE can do for me, but what can I do for the IAgrE "

References

Carruthers I (1993). Going, Going, Gone. Tropical agriculture as we know it. Purseglove Memorial Lecture, *Wye College Occasional Paper* 1992/93. ISBN 0 86266 056 4.

Spedding C R W (1992). Agricultural challenges – the alternatives. *The Agricultural Engineer* 48 (2) 38-41.

Precis of papers presented at the Annual Convention will be published in the next issue of The Agricultural Engineer

Destructive and non-destructive apple maturity and ripeness assessment

Saleh Ghafir and Keith Thompson

Fruit maturity at harvest affects both eating quality and postharvest life. This is especially true with climacteric fruits such as apples. If harvested too immature, apples will not ripen to an acceptable flavour – but, if fully ripe when harvested, they may have a short storage life and possibly also have a soft texture making them susceptible to damage during harvesting and handling.

The objective of this study was to compare three measurements using non-destructive techniques with physical and chemical changes which occur in apples, to determine whether these measurements could be used as methods of determining fruit maturity.

During maturation and ripening, physical and chemical changes take place which can be measured or assessed to provide a guide to optimum harvest maturity. One of these characteristics is the firmness of the fruit but assessment of this is a destructive method and relies on assessing a representative sample of fruits (Magness and Taylor, 1925; Kramer *et al.*, 1951; Mitchell *et al* 1961; Mohsenin, 1963; Lanza and Kramer, 1967; Abbott *et al.*, 1984, Studman and Yuwana, 1992).

Many non-destructive techniques have been described (Clark and Michelson 1942, Abbott *et al* 1968a, Abbott *et al* 1968b, Cooke 1970, Finney and Norris 1970, Finney 1971, Van Woensel and De Baerdmaeker 1983, Affeldt and Abbott 1989, Abbott *et al* 1992, Kimnel *et al* 1992).

Changes in the surface colour of fruit is also used to judge harvest maturity for Delicious apples (Crassweller *et al* 1991), peaches (Thai and Shewfelt 1990) and tomatoes (Thai *et al.*, 1990).

In this study, three non-destructive measurements of Golden Delicious apples were compared to the levels of some physical and chemical measurements which are known to vary with maturity and ripeness of individual apple fruits.

The non-destructive methods were:

the stiffness coefficient – measured by the fruit's response to vibration,

deformation of the surface – in response to the pressure of 1 Newton from an 8 mm diameter probe and

change in surface colour – as measured by a colour difference meter.

The physical and chemical parameters measured were starch level, soluble solids, acidity and firmness (measured by resistance to penetration of an 8mm diameter probe).

Harvesting procedure

Golden Delicious apples on M9 rootstocks grown at Horticultural Research International at East Malling in Kent were used in the study. The fruits were harvested randomly from the same four trees on 18th August, 1st September, 15th September and 29th September, 1992.

Professor A K Thompson is Head of Department and S A M Ghafir is a PhD student in the Post harvest Technology Department, Silsoe College, Cranfield University, Silsoe.

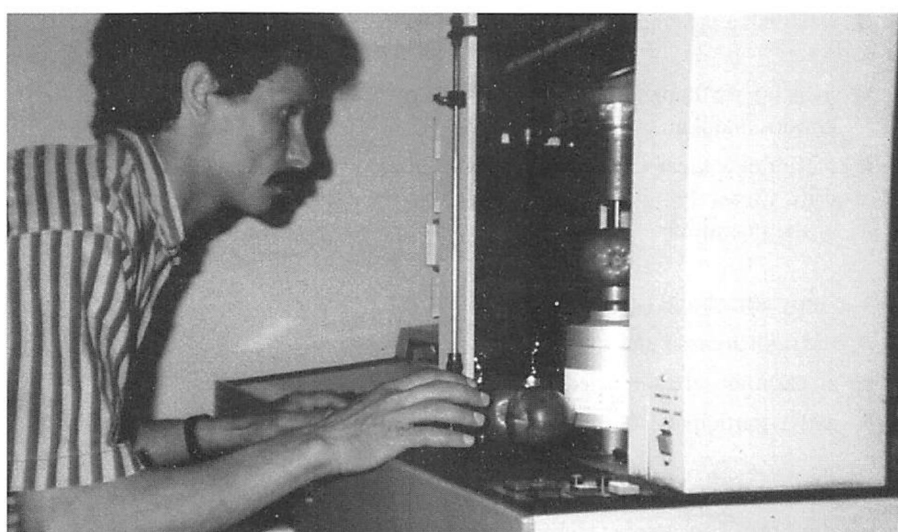


Fig 1. Measuring the fruit firmness using Instron Universal Tester.

Seventy-two apples were harvested on each occasion and each fruit was labelled, weighed and stored at 20°C and 80% RH. The fruits were divided randomly into 6 groups each of 12 fruits.

Measurements were made on one group immediately after harvest and subsequent measurements were undertaken after storage periods of 2, 4, 6, 8 and 10 days.

Measurements made

On each occasion the following measurements were made on each apple in the group:

Stiffness coefficient.

The fruit was placed on a force transducer, mounted on a vibrating exciter (Ling Dynamic System Model 200). The exciter was driven by a pseudo-random noise signal with a band width of 20Hz. A low mass accelerometer was placed on the opposite side of the fruit, in the same direction as the load cell. Blu-Tak was used to hold the accelerometer to the fruit surface. The signal was fed into a Hewlett Packard Spectrum Analyser (Model 3582A) which calculated the transfer function of the fourier transformation of the force signal.

Stiffness coefficient was calculated according to the following formula:–

$$f_2^2 \times m^{2/3} \times 10^{-6} \text{ (Cooke 1972)}$$

where: f_2 = second resonance frequency, m = fruit mass in grams.

Fruit deformation.

A maximum compression force of 1 N was applied to the fruit surface with an 8mm diameter probe in an Instron Universal Testing Machine (Model 2211). An appropriate full scale compression load deflection was chosen. The chart speed was 100mm per minute and the cross head speed was 2mm per minute.

Measurements were made on each fruit at five positions equidistant from one another around its equator, perpendicular to the stalk-calyx, and the deformation (mm) due to the application of the 1 N compression force was measured.

Surface colour.

Instrumental colour measurement was carried out using a tristimulus colorimeter (Minolta Model CR-200/CR-200b) employing ' 0^{0} ' viewing angle and an 8mm viewing aperture. This was standardised to a white plate (a^* = – 1.2, b^* = 2.8).

Because of colour variation of individual fruits, the mean reading for five points equidistant from one another around its 'equator' was used.

Results were recorded as a^* and b^* values, where a negative a^* value corresponded to the degree of greenness and a positive b^* value corresponded to the degree of yellowness. Readings were expressed as a percentage of maximum deflection.

Fig 2. Minolta colour difference meter for measuring change in skin colour during ripening

Fruit firmness.

This was measured using the same technique as described above for fruit deformation except that values were recorded for the maximum force required for the pulp to yield to the probe.

Starch.

Slices of fruit were immersed in a solution of 1% iodine in 4% potassium iodide (Cockburn and Sharples 1979). Blue/black colour developed in areas where starch was present and was expressed as a percentage of the total area of the fruit slice. The areas were measured using an electronic calliper.

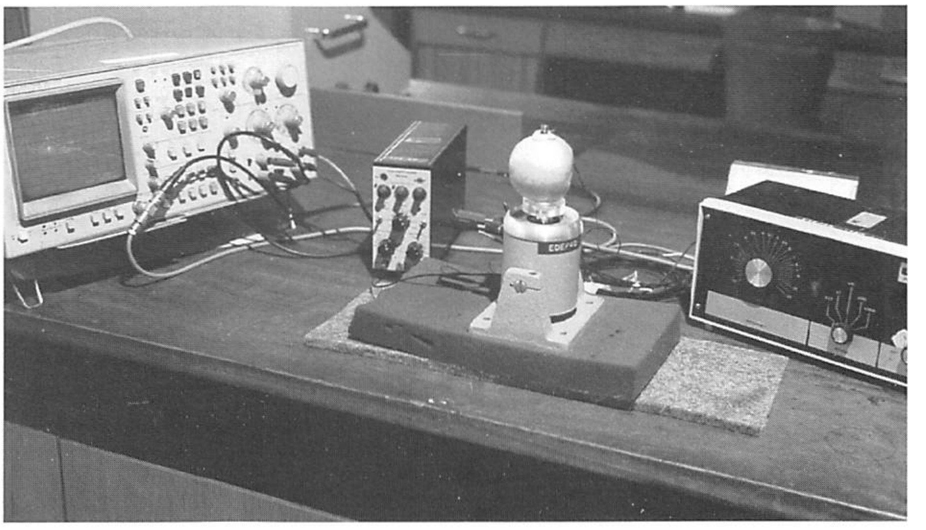


Fig 3. Equipment for measuring stiffness coefficient.

Total soluble solids.

Total soluble solids content of fruits was measured on the undiluted expressed juice using a refractometer (Atago Digital type PR1).

Titratable acidity.

Titratable acidity was measured on the expressed juice. Two aliquots of 10ml each were titrated against 0.3125N sodium hydroxide using promo thymole blue as an indicator.

Weight loss.

Each fruit was weighed upon removal from storage and its weight loss related to its weight just after harvest on the following basis:–

$$\frac{W_0 - W_1}{W_0} \times 100$$

where: W_0 = fruit weight just after harvest, and W_1 = fruit weight just after storage.

Results and discussion

The measurements of *stiffness coefficient* on freshly harvested fruit remained relatively constant (Fig 1A) while other parameters associated with maturation and ripening changed with time.

Abbott *et al* (1968a) showed that there was little or no loss of stiffness coefficient prior to normal harvest time in the three apple cultivars which were tested. Finney (1970) also found that at harvest the f_2m values of apples did not vary significantly with date of picking. However, a significant decreasing trend was shown during subsequent storage of the fruit irrespective of harvest date (Fig 1A). Van Woensel and De Baerdmaeker (1983) also showed that stiffness coefficient reduced during storage.

Anupun Terdwongworkul (1993 Silsoe College, unpublished) showed that stiffness coefficient was related to weight loss in stored apples in that where the fruit were stored at high humidity the stiffness coefficient remained constant and when they were stored at low humidity it reduced in proportion to weight loss.

It appears therefore that stiffness coefficient in apples is related to their moisture content or some related factor and would not be of use in measuring its maturity or ripeness.

Increasing *fruit deformation* at a constant compressive force corresponded to loss of firmness or softening.

Deformation was highest with the fruits from later harvests although the last picking date gave significantly lower (P = 0.05) deformation values which indicated that they were firmer than at the previous picking dates (Fig 1B). This change in the trend could be related to the high rainfall (67mm) in the time preceding the last harvest compared to less than 10mm for the earlier harvests.

Deformation was found to increase almost linearly during storage (Fig 1B).

Fruit firmness, as measured by penetration force, decreased as the fruit matured on the tree. Fruit firmness generally decreased during storage (Fig 1D). Panova (1975) also reported that apple firmness decreases during ripening.

The *colour* of fruit generally became less green (Figure 1C) and more yellow (data not presented) during the season . Fruits from the first two harvests retained their greenness during storage, but those from the latter two harvests became significantly (P = 0.05) less green during storage.

Starch content decreased as fruit matured on the tree and with time in storage with the difference being greater between the first picking date and the subsequent three (Fig 1E). This confirms the results of Adhikari *et al* (1989) who showed that the starch disappearance percentage increased gradually and was 54-55%, 123 days after full bloom stage.

The *soluble solids* content of fruit are mainly sugars which increase as harvest time approaches (Abbott *et al* 1968a). These results confirm the above and also show an increase in total soluble solids during storage (Fig 1F).

There were no interactions between harvest date and storage time for total soluble solids.

Highly significant decreases in *acidity* were found between all harvesting dates and levels during storage, which is an expected pattern (Fig 1G).

Weight loss during storage increased almost linearly (Fig 1H).

Generally there was little difference in weight loss during storage between the different harvest dates, but fruit from the first harvest lost weight at a greater rate than those from the subsequent harvests.

Many measurements show linear relationship

When individual measurements were plotted against each other many relationships were shown to be significantly linear (Table 1).
The non-destructive measurement of fruit firmness by deformation and the measurement of stiffness coefficient correlated well with each other and with weight loss during storage which indicates that perhaps they are both measuring fruit weight loss and not ripeness or maturity.
The measurements both of fruit greenness (a*) and yellowness (b*) gave lower correlations with weight loss than the other two non-destructive measurements but better correlations with firmness, soluble solids, starch and acidity, all of which are changing during fruit maturation and ripening.

Colour change the most likely indicator

The initial conclusions to this study would be that from the methods tested only the measurement of colour change gives an indication of the maturity or ripeness of Golden Delicious apples.

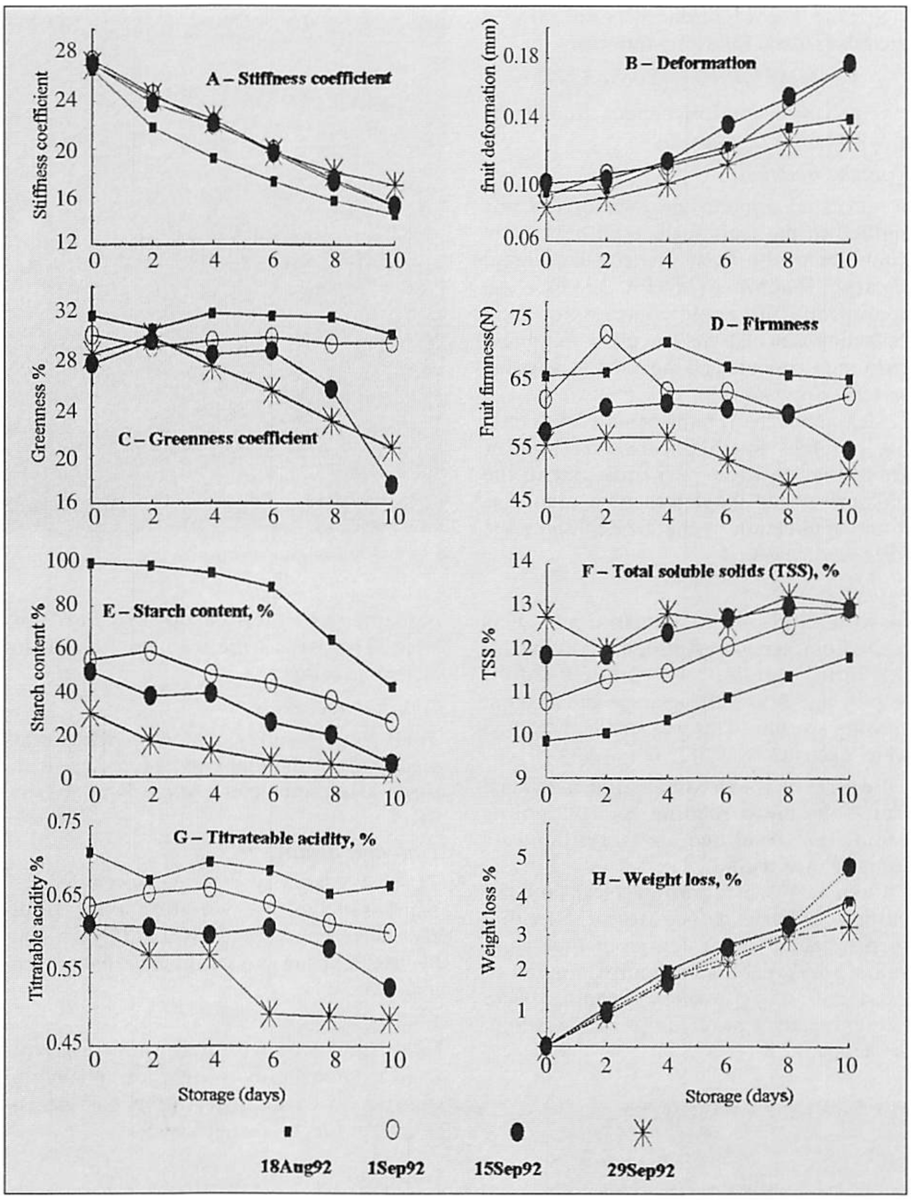


Fig 4. Effect of harvesting date and storage on Golden Delicious apples.

References

Abbott J A, Affeldt H A, Liljedahl L A (1992). Firmness measurement of stored "Delicious" apples by sensory methods, Magness-Taylor and sonic transmission. *J Am Soc for Hort Sci* 117, 590-595.

Abbott J A, Bachman G S, Childers N F,

Table 1. Linear correlation coefficients (r) of maturity assessment parameters for Golden Delicious apples.

Measurement	*Correlation coefficient* [1]							
	Stiffness	*Firmness*	*Acidity*	*Greenness*	*Yellowness*	*Deformation*	*TSS* [2]	*Starch*
Firmness	0.039							
Acidity	0.223*	0.605***						
Greenness	0.176	0.384***	0.386***					
Yellowness	–0.291***	–0.623***	–0.580***	–0.555***				
Deformation	–0.783***	–0.077	–0.197*	–0.286**	0.358***			
TSS	–0.218*	–0.458***	–0.306**	–0.632***	0.505***	0.347***		
Starch	0.223*	0.637***	0.702***	0.398***	–0.629***	–0.286***	–0.595***	
Weight loss	–0.913***	–0.064	–0.230*	0.350***	0.427***	0.830***	0.398***	–0.349***

Notes: 1) For correlation coefficients, ' n ' = 288 Significant differences are: *p = 0.05; **p = 0.01; ***p = 0.001
2) TSS Total Soluble Solids

Fitzgerald J V, Matusik K F (1968a). Sonic techniques for measuring texture of fruits and vegetables. *Food Technol.* 22, (5) 635-646.

Abbott J A, Childers N F, Bachman G S, Fitzgerald J V, Matusik F J (1968b). Acoustic vibration for detecting textural quality of apples. *Proc Am Soc Hort Sci* 968, 725-737.

Abbott J A, Watada A E, Massie D R (1984). Sensory and instrument measurement of apple texture. *J Am Soc Hort Sci* 109, 221-228.

Adhikari K S, Joshi S M, Divakar B L, Negi R S (1989). Assessment of apple fruit harvesting period by starch iodine test var. Peak's Pleasant. *Progr Hort* 21, 159-164.

Affeldt H A, Abbott J A (1989). Apple firmness and sensory quality using contact acoustic transmission. *Proc 7th Int Congr on Agric Engng, Dublin, Ireland* 3, 2037-2045.

Blampied G. Bramlage W J. Dewey D H, La Belle R L, Massey L M, Mattus G E, Stiles W C, Watada A E (1978). A standardised method for collecting apple pressure test data. *New York's Food and Life Sciences Bulletin* 74.

Clark H L, Mikelson W 1942. Fruit ripeness tester. *U. S. Patent 2*, 277, 037.

Cockburn J T, Sharples R O (1979). A practical guide for assessing starch in Conference pears. *Rep of East Malling Res St 1978*, 215-216.

Cooke J R (1970). A theoretical analysis of the resonance of intact apples. *Paper No. 70-345* ASAE St. Joseph, Michigan,

Cooke J R (1972). An interpretation of resonant behaviour of intact fruits and vegetables. *Trans Am Soc Agric Engrs* 15, 1075.

Crassweller R M, Braun H L, Baugher T A, Greenell G M, Hollendar R A (1991). Colour evaluation of Delicious strains. *Fruit Varieties J* 45 114-120.

Finney E E (1970). Mechanical resonance within Red Delicious apples and its relation to fruit texture. *Trans Am Soc Agric Engrs* 13, 177.

Finney E E, Norris K H (1968). Instrumentation for investigating dynamic mechanical properties of fruits and vegetables. *Trans Am Soc Agric Engrs* 11, 94.

Kimmel E, Peleg K Hinga S (1992). Vibration modes of spheroidal fruits. *J Agric Engng Res* 52, 201-213.

Kramer A, Aamlid K, Guyer R B, Rogers H (1951). New shear-press predicts quality of canned limes. *Food Engng.* 23, 112-187.

Lanza J, Kramer A (1967). Objective measurements of graininess in apple sauce. *Pro Am Soc Hort Sci* 90, 491.

Magness J R, Taylor G F (1925). An improved type of pressure tester for determination of fruit maturity. *US Dep of Agric Circ* 350, 8pp.

Michell R S, Casimir D J, Lynch L J (1961). The maturometer instrumental test and redesign. *Food Technol* 15, 415.

Miller B K, Delwiche M J (1989). A colour vision system for peach grading. *Trans Am Soc Agric Engrs* 32, 1485-1490.

Mohsenin N (1963). A testing machine for determination of mechanical and rheological properties of agricultural products. *Penn Agric Expl Stn Bull* 701.

Panova R R (1975). Changes in the flesh consistency and starch content in fruits of some apple cultivars during ripening. *Cradinarki Lozarska Nauka* 12, 32-40 (From *Hort Abstr* 64:11035).

Studman C J, Yuwana. (1992). Twist test for measuring fruit firmness. *J Texture Studies* 23, 215-227.

Thai C N, Shewfelt R L (1990). Peach quality changes at different constant storage temperatures: Empirical models. *Trans Am Soc Agric Engrs* 33, 227-233.

Thai C N, Shewfelt R L, Garner J C (1990). Tomato colour Changes under constant and variable storage temperatures: Empirical models. *Trans Am Soc Agric Engrs* 33, 607-614.

Van Wonsel G, De Baerdemaeker J (1983). Mechanical properties of apples during storage. *Lebensm. Wiss. u. Technol.* 16, 367-372.

Encouraging innovation

Wrekin Branch (DC)

In what has now become an annual event, the Branch members get a chance to see the research and project work of Harper Adams College's Ag. Eng. Department.

With around 120 engineering undergrads 'on the books', that means there are each year some 35 – 40 final year projects, seven group projects, two or three marketing projects plus various staff research projects on which students are often involved — plenty for the members to see.

More than 50% of the projects are independently supported and details of many projects could not be revealed for reasons of confidentiality.

Waste not ...

Work on improving the design of slurry aerators is occupying the time of Edwin Ratcliffe and Karl Randall. Their scheme for treating pig and cattle slurry involves ten tanks into which air is pumped from a manifold complex. Their investigations are being funded by the Farm Electric Centre.

In the early stages of development is a municipal waste composting venture headed up by Isobel Colclough, a chemical engineer. working in conjunction with the local Wrekin Council.

Stable relationship

Predicting the centre of gravity of a machine before it is even built is the project of Paul Warmsley and Philip Wilson. They devised a spreadsheet system which could provide the answers from c. of g. data of each major component. An added benefit of this system is that components could be 'moved around' and changes predicted.

Picking the best

Jeffrey Muriithi is investigating the use of ultrasonics to determine the state of ripeness of avocado pears, a notoriously difficult task to do visually.

Alex Keen is using plants to lift water from the ground. In areas where there is limited rainfall but abundant ground-water his 'Air-Well' traps will transpire water and condense it — you can imagine the advantages of this.

A visit to this College's engineering research function cannot fail to create a feeling of optimism. There's a lot of innovative engineers coming through.

Mapping by the 'stars'

West Midlands Branch (M S)

Massey Ferguson's initiative to use the Global Positioning System (GPS) on their combines has opened the eyes of the agricultural engineering world to the opportunities and potential of this system.

The West Midlands Branch, like several others over the last year, recognised the significance of this development and arranged to find out more. The speaker for the evening was Mark Moore from M-F's Training Centre.

Yield mapping is accomplished by linking two systems – a yield meter on the clean grain elevator and the satellite GPS complex. The yield meter is accurate to $^1/_2$% (it was 40kg out in 70tonnes at one point); the GPS to around 5m when linked to a farm receiver. The 24 satellites, orbiting 11000 miles up, cost $12 billion and were originally intended for military use. In this capacity they can put a missile down a chimney pot, but in 'civvy' mode they are 'down rated' to about 100m accuracy – hence the need for a farm base station to enable computation of position by a differential system.

So that's an outline of what you get for a £500 licence fee, but what are the benefits to management?

Once computed, the yield map of a field is used to initiate investigations into what is causing the variations. Limiting factors can be identified and, hopefully, rectified.

Some parts of a field will never yield as well as others, no matter how good the growing conditions. After a few years of data collection these areas can be identified and so, by utilising the next phase in this system's development — GPS on drills, sprayers and fertiliser spreaders – the inputs can be tuned to the soil potential and the overall gross margin maximised.

Evaporative cooling and its applicability to livestock housing in Ethiopia

The basic requirement of a livestock shelter is that it should alter the environment for the benefit of the animals. Control of the environment involves four psychrometric factors of which the environmental temperature is the most important and influential. In hot regions of the world, control of house temperature is very important.

Assefa Mekonnen here reports on a study to establish the characteristics of evaporative cooler pads under different conditions and to assess the applicability of evaporative cooling systems to three selected regions of Ethiopia.

Ethiopia has the largest population of livestock in Africa but little attention has been made to proper livestock housing and environmental modifications. As a result, production has been reduced and only limited benefit gained from this sector.

As crop production makes only a small contribution to the people's needs, maximisation of products from animals is of paramount importance. Crop failures have to be subsidised by increased production from livestock.

Goal of environmental modification

The goal of environmental modification is to provide an environment conducive to high productive efficiency for the animals.

An animal under a high degree of thermal stress will reduce feed intake and expend energy to maintain thermal equilibrium. The expended energy would otherwise be available for useful production.

Problems associated with thermal stress, in addition to a decline in productivity, as shown in Fig 1.1, are a general decline in reproductive efficiency and an increase in disease susceptibility.

Evaporative cooling offers best solution

Several environmental modification strategies can be utilised for reducing the severity of heat stress. These include:

- mechanical ventilation,
- evaporative cooling,
- zone cooling,
- mechanical refrigeration and
- various shade structures.

With the exception of evaporative cooling, none of the above options is economical or effective under extreme temperatures where the ambient air temperature exceeds the design inside temperature.

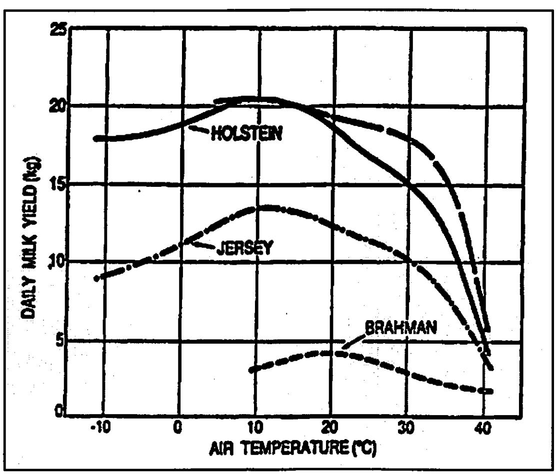


Fig 1.1. The effect of air temperature on milk yield for various breeds of dairy cows.

Evaporative cooling is an adiabatic process in which heat is neither added nor removed from the environment. Removal of sensible heat required to evaporate water lowers the ambient temperature as shown in Fig 1.2. Evaporative cooling is effective in certain regions of the world where relatively high dry-bulb temperatures and low relative humidities are experienced.

Much of the criteria for evaporative cooler design is based on the experience of industry rather than from research data (Durward & Wiersma, 1974).

Criteria are airflow and saturation efficiency

Cooling capacity depends upon the amount of air flow and the saturation efficiency. Saturation efficiency, the effectiveness with which water is transferred to the air, is dependent upon the characteristics of the evaporator pad and the air velocity and water flow rate through the pad.

A number of investigations (Hahn and Osburn (1970), Durward *et al* (1974), Durward *et al* (1974), Timmons *et al* (1983)) has considered the effectiveness of evaporative cooling in livestock production. Such investigations are, however, site specific and their results can only be applied to the particular evaporator pad and ambient conditions.

Objectives of the study

The research reported in this paper had the following objectives:

- To study the characteristics of evaporative cooler pads under different conditions using a model animal and

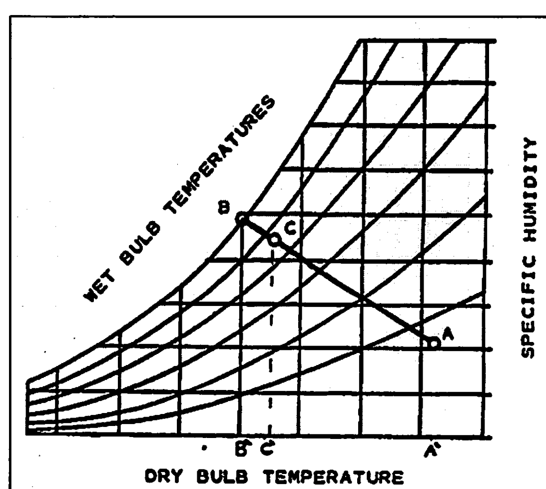


Fig 1.2. Evaporative cooling process on psychro-metric chart from point A to point C.

A Mekonnen is a Lecturer in the Department of Agricultural Engingeering, Alemaya University of Agriculture, Dire Dawa, Ethiopia.

building.

- To assess the applicability of evaporative cooling systems to three selected regions of Ethiopia.

The study was carried out at the Department of Agriculture and Food Engineering, University College Dublin, in the summer and autumn of 1990.

Materials and Methods

— the chamber

A psychrometric chamber (4.16m x 2.4m x 1.8m) was designed and constructed. The chamber simulated the situation in which sensible heat production, latent heat production and surface temperature were produced approximating to outputs of cows of different sizes and breeds.

The volume of the chamber was dictated by the ventilating capacity of the air conditioner attached to one side of the wall and had a floor area of $10m^2$ which is sufficient for a 500kg dairy cow. Fig 2.1 shows the plan view of the psychrometric chamber.

The air conditioner unit could provide ranges of dry-bulb temperature, relative humidity, air velocity and water flow rate for the cooing system considered. Figs 2.2 and 2.3 show the equipment lay-out and the water distribution of the cooling system.

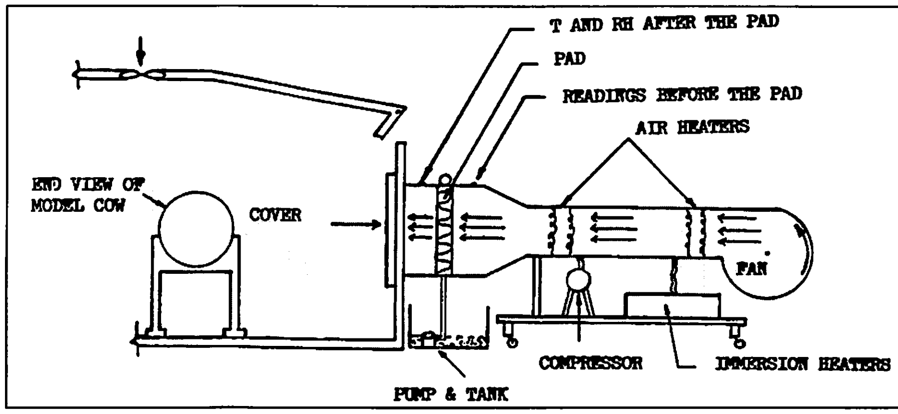


Fig 2.2. The evaporative cooler with the air conditioner (as attached to one side of the chamber).

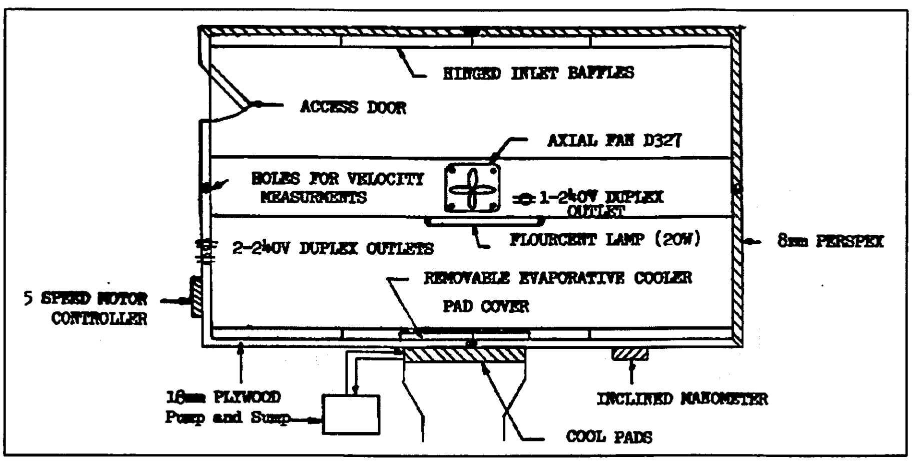


Fig 2.1. Plan view of the chamber.

— the evaporator pads

Two types of evaporator pad (a Kool-cel pad and an Aqua-cel pad) were studied to assess the effects of air velocity and water flow rate on the saturation efficiency and pressure drop across the pad. Ranges of dry-bulb and wet-bulb temperatures were used to identify the effectiveness of the system for the range of supply air states.

Kool-cel pads are constructed from fluted paper which is highly resistant to decay. The average density is $33kg/m^3$ and thicknesses of 100mm, 150mm and 200mm were used in the study.

Aqua-cel pads consist of synthetic fibres, firmly bonded together and coated with an unique super-absorbent cellular foam. The backing is galvanised and fuse bonded to PVC-coated welded wire. The density of the pad is $26.7kg/m^3$ and thicknesses of 38mm, 57mm and 76mm were studied.

For each experimental run (a total of 96 runs was conducted), the following information was recorded:

- dry-bulb temperature
- relative humidity
- static pressure drop across the pad
- air (or pad face) velocity
- water flow rate

The results were interpreted for their applicability in three different localities of Ethiopia using meteorological data analysis.

Results and discussion

Saturation efficiency

Saturation efficiency (E) is defined as the ratio of the actual change in saturation achieved relative to the potential change, assuming steady state conditions. At 100% saturation efficiency, the output relative humidity will be 100% and maximum temperature reduction will be achieved. From Fig.1.2:

$$E = \frac{T_i - T_o}{T_i - T_s} = \frac{Rh_i - Rh_o}{Rh_i - Rh_s} = \frac{AC}{AB}$$

The pad face test air velocities were chosen as being those most commonly used in evaporative cooling systems.

Influences on saturation efficiency

—air velocity

As the air velocity is increased from 0.75 to 1.5 m/s the saturation efficiency appears to decrease as shown on the graph (Figs 3.1 and 3.2) and then increases at about 1.5m/s.

The decrease of saturation efficiency with air velocity is accounted for the greater contact time of the warm air as it passed through the wetted pad. As the contact time is increased, the water will have more chance to absorb heat from the warm air passing through it and there will be larger temperature reduction or more evaporation will take place. As the air velocity is increased, air flow will change from laminar to turbulent which will have the effects of breaking up the layered films, increasing the vapour pick-up opportunity and increasing evaporation. This is seen at about 1.5m/s air velocity.

— pad thickness

As the thickness of the pad is increased, the saturation efficiency for all velocities is

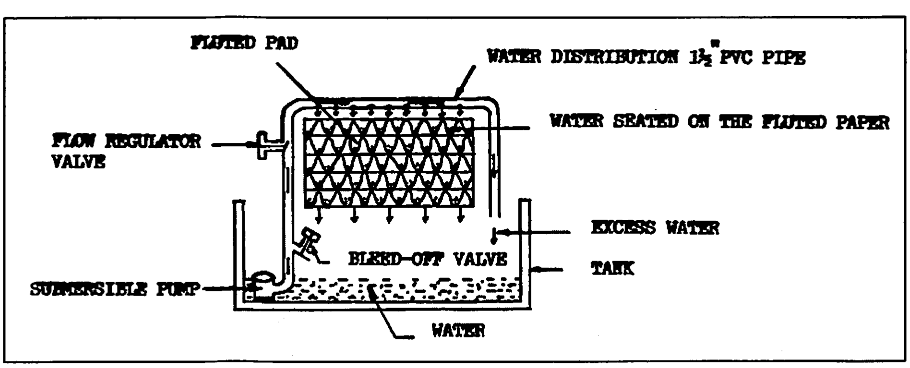


Fig 2.3. The pad and water distibution system.

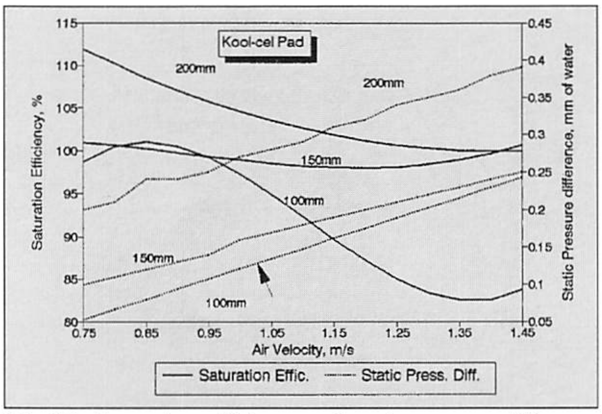


Fig 3.1. Saturation efficiency and static pressure difference Vs air velocity.

found to be higher. This is attributed to the longer contact time between the warm air and water, and the greater wetted area of the thicker pad. This is true for both Kool-cel and Aqua-cel pads. For the same air velocity, a Kool-cel pad has a higher saturation efficiency than an Aqua-cel pad.

The relationship between static pressure difference and air velocity is almost linear (Figs 3.1 and 3.2 — air velocity of 1.5m/s). The static pressure difference increases with pad thickness and is higher for Kool-cel pads than Aqua-cel pads for the same air velocity, due to the different construction or density of the pads.

— water flow rate

As incoming warm air temperature cannot be reduced to less than that dictated by

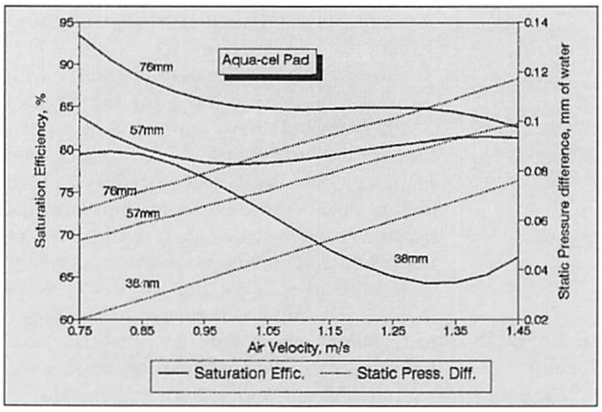


Fig 3.2. Saturation efficiency and static pressure difference Vs air velocity.

the capacity of the cooling system, there will be a maximum value of the saturation efficiency which can be achieved. This is shown in Figs 3.3 and 3.4 as all curves converge to one point.

Higher flow rates result in increased values of saturation efficiency. However, more energy is required to pump the amount of water and extra costs are entailed. As shown in the results, optimum saturation efficiency was found at a flow rate of about 3l/min. Higher saturation efficiencies could be attained at lower flow rates, but the need for thicker pads would impose extra expense. A compromise has to be made between them.

Kool-cel pads have higher saturation efficiencies compared to Aqua-cel pads at similar water flow rates.

— dry-bulb temperature

Both pads were tested at a range of dry-bulb temperatures.

Temperatures during tests tended to vary with the outside weather.

Generally, temperatures from 26.6°C to 30°C were investigated with other variables being kept constant (ie. air velocity, flow rate and relative humidity).

The saturation efficiency is acceptable for all temperature ranges tested but it tends to level-off as temperature increases.

Generally both pad types could reduce temperature to a lower value for the range of temperatures considered, with Kool-cel pads having higher saturation efficiency values.

The relationship between wet-bulb temperature and saturation efficiency is shown in Fig 3.5. Output relative humidities were between 77%-91% when using either the 100mm Kool-cel pad or the 38mm Aqua-cel pad.

— relative humidity

An evaporative cooling system is more effective in areas of low humidity since the system increases the humidity level of the house by water evaporation. For this reason, a range of relative humidities (36%-65%) which could be encountered in the hotter regions of Ethiopia was tested.

In some of the tests, the saturation efficiency increased with the increasing ambient relative humidity.

For Kool-cel pads, an acceptable relative humidity level could be achieved for a 100mm pad thickness. With thicker pads, the output relative humid-ity was almost at saturation which is undesirable from both the point of view of animal health and the fabric of the house.

In the case of the Aqua-cel pads, the output relative humidity was lower but the saturation efficiency which indicates the magnitude of temperature reduction is also lower compared to Kool-cel pads.

Weather data study

To assess the potential of evaporative cooling pads in hot areas of Ethiopia, three sites (Bahir Dar, Dire Dawa and Jijiga (Fig 3.6)) were selected. These areas have relatively high temperatures and are potentially promising for animal production. Two of the stations selected are animal production research sites of Alemaya University of Agriculture.

The meteorological data obtained from

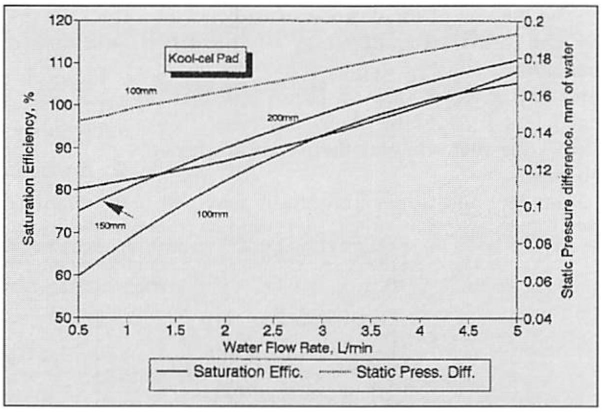


Fig 3.3. Saturation efficiency and static pressure difference Vs water flow rate.

the Ethiopian Meteorological Service Agency include dry-bulb temperatures and relative humidities from 1980-1989 as average monthly values. Months with high average temperatures were considered since they are critical to the design of a cooling system. These were March, April and May for Bahir Dar and Jijiga and June, July and August for Dire Dawa.

In order to analyse the data, the mean monthly temperatures (with a range of 25.5°C-33.4°C) for the design months were grouped, with each group having a 1.5°C interval.

By the same method, five groups of relative humidity observations (range 25%-79% RH) were formed.

Graphs showing percentage of obser-

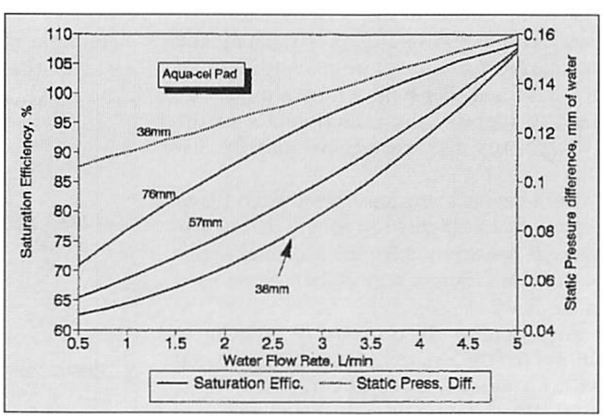


Fig 3.4. Saturation efficiency and static pressure difference Vs water flow rate.

vations against mean of the group temperature and relative humidity for each site are shown in Figs 3.7 to 3.12.

At *Bahir Dar*, the majority of dry-bulb temperatures and relative humidities lie between 28.2°C-29.5°C and between 41%-62% respectively.

The laboratory study showed that air supply within this range yielded a high saturation efficiency and the humidity level was as high as 91% in some cases depending on other input values. For Kool-cel pads thicker than 100mm, humidity output was up to saturation level.

A properly designed evaporative cooling system would work effectively with these ranges of weather data for Bahir Dar.

At *Dire Dawa*, most of the temperature observations are between 32.8°C and 34.7°C and the mean relative humidity is 40.2% for the whole month of June and between 43.6% and 51% for July and August.

The Dire Dawa station is in a high temperature and low relative humidity area where an evaporative cooling system could be applied. For example, for a 100mm thick Kool-cel pad, the output humidity and temperature are reasonable for livestock when inputs of dry-bulb temperature and relative humidity in the above range are used.

At *Jijiga*, most of the average maximum records lie between 25.9°C and 29.6°C and the mean relative humidity values fall between 62.4% and 75%. This station is in an area of high humidity. The experimental results indicate that for an input humidity level above 62%, the output humidity will be at saturation for 100mm Kool-cel pad with a water flow rate of 3l/min and air velocity of 1.5m/s. A lower relative humidity output can be achieved with an Aqua-cel pad but at a lower saturation efficiency.

Unless the system is used with a dehumidifier it would clearly be difficult to cope with the resulting high humidity levels and in this case humidity control would be the main task.

Acknowledgements

The author would like to express his gratitude to Prof V A Dodd for his unreserved advice and help throughout the work and the Department of Foreign Affairs of Ireland for financing the project. I wish to extend my thanks to Mr J Gaynor for his assistance in the construction of the chamber and the set-up of the model animal.

References

Armstrong D V, Wiersma F (1985). Effects of evaporative cooling under a corral shade on reproduction and milk production in a hot arid climate. *J. Dairy Sci (supp 1)*, 68:167.

Canton G H, Buffington D E (1982). Inspired air cooling for dairy cows. *Trans. ASAE*, 25(3): 730-736.

Canton G H, (1983). Evaporative cooling effects on mature, male broiler breeders. *Trans. ASAE*, 26(6): 1794-1797.

Dodd V A (1991). Personal communication.

Durward S, Wiersma F (1974). Design criteria of evaporative cooling for agricultural applications. *ASAE pap. no 74*-4527.

Esmay M L (1986). *Environmental control of agricultural buildings*. AVI Pub Co, West Port, Connecticut.

Hahn L, Osburn D D (1970). Feasibility of evaporative cooling for dairy cattle based on expected production losses. *Trans. ASAE* 13(3): 289-284.

Hellickson M A (1983). Ventilation of agricultural structures. *ASAE Monograph No 6*.

McNeill S G, Walker J N (1983). Performance of evaporative coolers for mid-south gestation housing. *Trans. ASAE*, 26(1): 219-224.

Mekonnen A (1991). Livestock housing in hot climates: A study of microclimate modifiers using a laboratory scale building. *M Engng Sci thesis*, Dept Ag and Food Eng, University College, Dublin.

Peterson R J (1955). Evaporation from surfaces. *ASHRAE J.* (Heating, piping and air

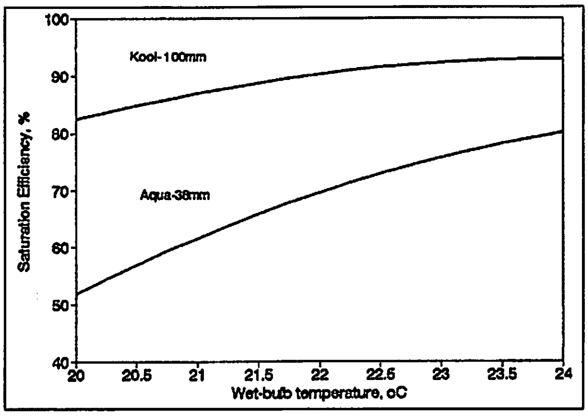


Fig 3.5. Saturation efficiency Vs wet bulb temperature.

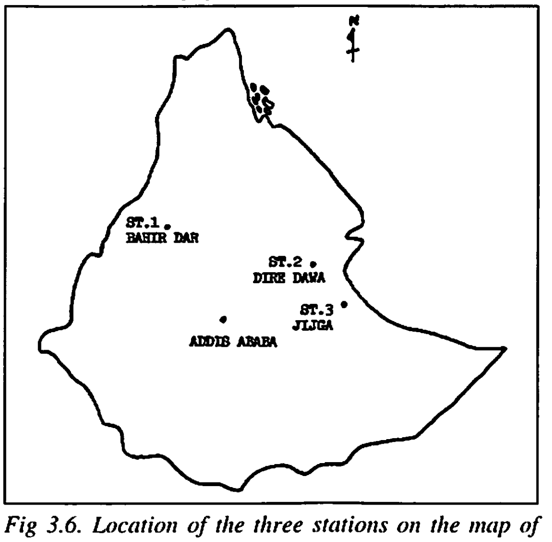


Fig 3.6. Location of the three stations on the map of Ethiopia. Scale 1 : 12,400,000

Conclusions and Recommendations

The characteristics of two commercial evaporative cooling pads were studied in the laboratory using an air conditioning unit to simulate hot weather ventilating air.

The following conclusions are put forward:–

- Pad face velocity has negative correlation with saturation efficiency for laminar flow (low velocities) due to high contact time and this relationship will be positive for turbulent flow at high velocities. The turning point depends on the pad type and thickness.
- Saturation efficiency increases with water flow rate up to a specific value after which it is constant. The maximum water flow rate is determined by the moisture holding capacity of the pads.
- For the same inputs, Kool-cel pads have a higher saturation efficiency and static pressure difference than Aqua-cel pads.
- Highest saturation efficiency and an acceptable output relative humidity was found with a Kool-cel pad of 100mm thickness when the air velocity was 1.5m/s at 3l/min water flow rate.
- As the thickness of the pad increases, the saturation efficiency increases and the output relative humidity will be higher and in some cases it can rise above saturation. The presence of free water and experimental error are two reasons given for this apparent discrepancy.
- The saturation efficiency of pad increases with input dry-bulb temperature up to a specific value, determined by the cooling capacity of the system.
- Evaporative cooling pads appear to have applications in the housing of livestock in the hot climates of Ethiopia as indicated by the meteorological data studied, except for high humidity sites.
- A temperature reduction of up to 10°C was achieved with the cooling pads used.

Recommendations for further work include the following:

- The cooling pads should be tested for more ranges of temperature and humidity.
- The research be extended to a full scale livestock environment for further studies.
- The use of local materials as media for evaporative cooling pads should be considered and studied.

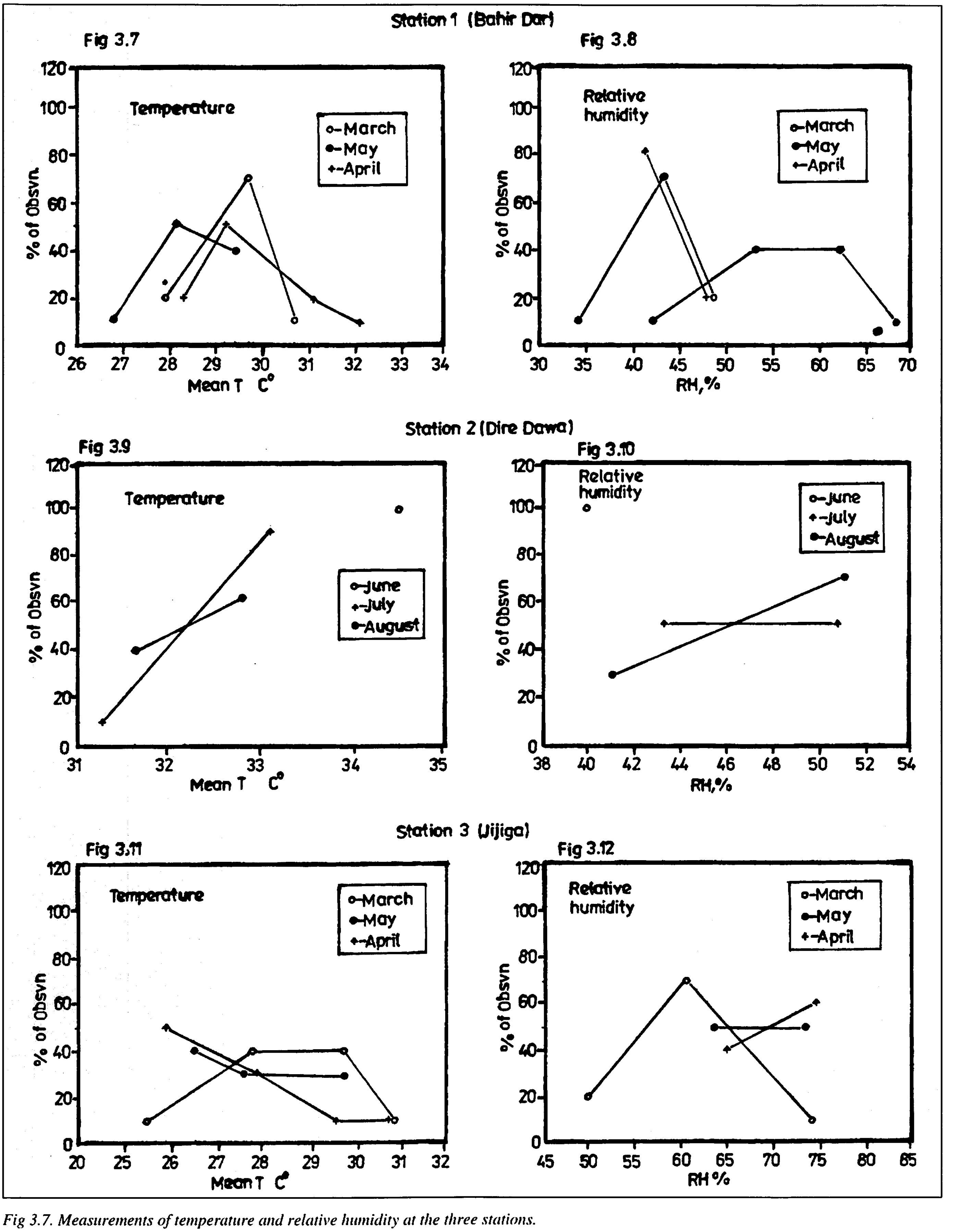


Fig 3.7. Measurements of temperature and relative humidity at the three stations.

conditioning).

Timmons M B (1983). Experimental evaluation of poultry misting systems. *Trans. ASAE* 26(1): 207-212.

Wiersma F, Armstrong D V (1989). Microclimate modifications to improve milk production in hot arid climates. *Proc CIGR*, Dublin, 4-8 Sept, 1989. 1433-1439.

Weichert W T, Wiersma F (1974). Field practice of horizontal evaporative cooling pad applications. *ASAE Pap. No* 74-4552.

Membership matters...

THE NEWSLETTER OF THE INSTITUTION OF AGRICULTURAL ENGINEERS

Unification — new proposals for engineers

After an initial rebuff on the idea of a series of 'Colleges' representing the engineering profession, the Policy Group which is trying to find a way of unifying engineers from all disciplines has reached broad agreement on a revised structure.

In an open letter to the Presidents of the Institutions affected, the Chairman of the Stage II Policy Group, Sir John Fairclough FEng, outlined the latest proposals:-

A new Engineering Council to be responsible for establishing overall policies and to delegate powers to two Boards to execute these policies.

- The Board for Engineering regulation (BER) — to set, review and monitor education and training standards (both *ab initio* and continuing) and maintain a register of qualified engineers.
- The Board for the Engineering Profession (BEP) — to initiate and facilitate activities to provide a 'single voice' on engineering affairs.

The New Relationship Working Group has been asked to press on with the detail within this basic framework. Sir John's target is to have detailed proposals to put to the profession by the autumn. The Statuary Powers Working Group has also to work within that time scale. Their remit is to establish the need, or otherwise, for new legislation to regulate the profession.

Overall, Sir John is pleased with the progress made and is confident that this basic framework will provide a sound basis for a New Relationship.

Bigger neighbourhood ?

Regular readers of this 'rag' will be familiar with the Engineering Council's initiative which goes under the heading of "Neighbourhood Engineers". It's a scheme which links professional engineers to secondary schools and though it has been a great success over the five or six years it has been going (10000 engineers linking with almost 3000 schools) there is still much to be done. Can you help? Could you give an hour or two of your time to spreading the word that (agricultural) engineering is the profession to be in? That's what it's all about — attracting the attention of youngsters in their formative years.

Think positive

So why not have a go? You can spend as much or as little time as you can afford on it, there's no minimum. You don't need experience in making presentions to groups – there is full support available from the EC through their Regional centres. You don't need vast years of experience in a high-powered position with a multi-national company either. Even if you consider your job mundane and insignificant, think positive. The youngsters out there are hungry for information on the real world and, with a little help if needed to emphasise the benefits, will be enlightened and appreciative.

Spin off

Time spent participating in this initiative is invariably very rewarding – the dawning of realisation on a 14/15 year old's face is a pleasurable sight indeed. There are other potential spin-offs too. It gets your name and that of your company known. It gives you an appreciation of the constraints under which schools have to work and a better understanding of training needs post-school, and it improves presentation skills which must help one's CPD. Mike Hurst tells me that on one such foray a friend of his met his (eventual) partner. Now, if you're single, there's a good incentive. If you're already married I should keep quiet about that bit when you're telling the spouse !

Student Membership of the IAgrE

Over the last few years, student membership of the Institution has been available at the very low rate of £5 per year (£6 in 1994). Since the subscription was so low, such student members were not sent their own copies of the journal The Agricultural Engineer, but their college libraries were sent extra copies.

The system has been kept under review and it seems that some students have felt they have not been getting good value from their £6 because they did not receive their own copies of the journal. Council has, therefore, decided to revert to the previous practice of having one grade of membership to cover both mature and younger students. They will all receive individual copies of the journal, plus the usual mailings from the Institution.

We are not now accepting new members at the £6 rate, although existing students on the low rate will be given the option of continuing until the end of their courses. The fee for the new student grade will be £12 per year. It will still be a loss-leader for the Institution, and we hope students will appreciate that it remains very good value.

Have you got an old degree ?

Many of you will know that the academic standard for registration as Chartered Engineer is a BEng Honours degree. Agricultural Engineering qualifications which are currently accredited by the Engineering council for Chartered Engineer status are BEng Honours degrees from:

- Harper Adams Agricultural College
- Silsoe College
- University of Newcastle upon Tyne.

With effect from the end of 1995, the **Engineering Council** will be much more stringent and **cease to accept some UK Engineering and Science qualifications** which previously were acceptable. From then, some applicants will have to take three supplementary papers from an Engineering Council list. In addition, many applicants will have to show evidence of further engineering experience.

ACT NOW — don't leave it until it is too late. If your degree is not a BEng Honours, you should consider registering your qualifications with the Engineering Council There is a small fee, which for 1994 is only £4.30, and it will save taking further exams.

Give our Membership Secretary, Sheila Hollowell, a ring without delay, and find out whether it would benefit you.

No action is required by anyone who is already registered at either Stage 1 or Stage 3 Chartered Engineer.

50 Years

Going for gold

In this issue are the first two of what I hope will be regular appreciations of members who have 50 years of membership to their credit. They are the briefest of accounts, regrettably, space is the limiting factor not the will to write a full biography of each and every one. I hope, though, that it gives readers an indication of the great agricultural engineers in our midst and in our membership, and encourages the younger generations to strive to emulate their achievements.

This series was brought about through the sadness of writing obituaries for members past. Obituaries are so necessary to honour and recognise the achievements of those no longer with us, but how more pleasant it is to honour and recognise the achievements of those still with us and still going strong at this memorable stage in their association with our Institution. In my contact with those members it has been a most pleasurable experience to talk over their careers — exciting in many ways, humbling in others. They have lived through, and made significant contributions to a profession which has been, and still is, full of change. In the last 50 years, developments have come thick and fast; it has been an exciting time in which to spend a working life.

One is tempted to look back nostalgically and think: "Ah, those were the days, it will never be like that again". But won't it? Our profession is still going through a period of rapid change. New techniques and new opportunities come into focus almost every day. I'm sure the 1990s will be looked upon in the 2040s as a great time to have been at work. What happens between now and then depends on you !

Building bridges . . .

. . . both literally and metaphorically has been the goal in life for **Bernice Bernard**, and it has been (and still is being!) accomplished with aplomb.

Bernice graduated from Manchester University with a degree in Mechanical Engineering and was soon a key figure in the drawing office of Salopian Engineering – her first taste of agricultural engineering. Our profession is noted for its wide spectrum of expertise. Bernice realised that quality, and gained a Master's degree in Structural Engineering after taking up an appointment in British Railway's Research Department.

Her work in that organisation earned many accolades. Several years were based in Utrecht as a Senior Scientific Officer – an appointment which offered opportunities for extensive international travel.

Bernice has had some part to play in many bridges throughout British Rail and in Ceylon, Canada and Europe. But creating bridges of a metaphorical nature is another area in which she has received praise for her work, and quite rightly so too. Her international experiences provided the opportunity to create and maintain links with other engineering disciplines around the world – there aren't many countries in the world untouched by Bernice's diplomacy and co-operation.

At home, her involvement in national engineering is legend. She was an elected member of the Engineering Assembly from its inception and is involved with Engineering Council matters even today. Her experience and wisdom has been sought across all circles of the engineering profession – education; young engineers; Neighbourhood Engineers and beyond – the list includes many of the professional initiatives taken in the last 50 years.

International travel on the scale undertaken by Bernice cannot fail to open one's eyes to the beautiful world we live in and to generate abhorrence towards those who wish to destroy it. Yet it is engineers who so often provide the tools for that destruction. Bernice was early to realise this and has demonstrated her concern – as founder member of the International Network of Engineers and Scientists for Global Responsibility (and still an active Council member); and elected to senior roles in Engineers for Nuclear Disarmament. She is a respected voice in a concerned profession, keen to encourage international co-operation between the disciplines of engineering to make the world a safer and better place to live in.

Well done, Bernice, we raise our hat to your energy and endeavours. Your support over the last half-century is highly valued. We wish you continued success and are humbled by your achievements.

Photo opposite: Bernice receives her 50-year membership certificate from Brian Finney, President of the Institution.

From hand to herringbone

The name Gascoigne is synonymous with dairy engineering the world over. Much of the credit for that state of affairs goes to a member who, this year, celebrates half a century of membership of our Institution — Mr **F N Gascoigne** FIAgrE.

Born in 1912 in Teddington, Middlesex, he entered the world of civil engineering from the start — his father was an early pioneer of reinforced concrete within these shores. It was on one of his many trips to America to learn about this technique that Mr Gascoigne Snr came across the construction of steel silos. He began importing these structures and this brought him into contact with the dairy industry. He noticed a degree of dissatisfaction amongst farmers with the milking machines of the time so, being an innovative man not afraid to take the initiative, he set about improving the design and marketing of Gascoigne's milking machines. That was in 1922.

Neville Gascoigne (later affectionately known as "Mr Neville" by all employees within the Gascoigne Company and, indeed, throughout the agricultural engineering industry) left school in 1928 and for a few years was involved with bacteriology and refrigeration at the National Institute for Research in Dairying, Shinfield, before joining his father's company as a Field Fitter.

His rise through the ranks of the company to Sales Director in 1936, the year the company 'went public', was on merit not by virtue of his being the boss' son. Agricultural shows became part of his life and he revelled in the contact with users of the company's products. Gascoignes were a dynamic company and the feed-back gained from these shows meant that the Gascoigne stand always seemed to have something new and innovative to offer.

The company went from strength to strength gaining a wealth of honours for its products, not least the Royal Warrant from King George VI which was later transferred by H M Queen Elizabeth II to Neville Gascoigne, who took over from his father and continued that momentum for several decades until his retirement in 1971. Retirement gave him the opportunity to further reduce a respectable handicap – at golf, between consultancy assignments. Playing golf had given him some invaluable contacts within the dairy engineering industry and beyond, as indeed has membership of our Institution.

Now not as physically active as he would no doubt like to be he is, nevertheless, endowed with a sharp mind and a subtle wit. He is, and will ever remain so, one of the key figures in the evolution of our industry. It is to our industry's and our country's shame that we hear that his book on 'Gascoignes the company' is stumbling at the final hurdle — getting into print. There must be someone out there who is prepared to help., maybe Gascoigne Milking Equipment Ltd who owe so much to this man and his father. Now that would be a nice touch.

Admissions – A warm welcome to the following new members:

Fellow: R M Friedlander (Essex)

Member: G C Obiechefu (Bedford)

Associate Member: R Adu (London); G K Anornu (London) D H Crowe (Wales); D F Giles (Staffs); R G Hallchurch (Wilts); P Joyce (Cambs); T Leyman (Belgium); J P Middleton (Kenya); P Mushove (Irish Republic); S S Parris (Guyana); C T Pratt (Warks); P E Walmsley (Shrops)

Associate: G E Broughton (Kent); E Hindmarsh (Tyne & Wear)

Student: N V Askew (Shrops); R W Birkbeck (Cumbria); B O Donohue (Bedford); J D Fashanu (Tyne & Wear); I J Sayers (Suffolk); J L Smith (Warks)

Transfers – congratulations on achieving a further phase of their professional development to:

... to **Fellow:** A D Gracey (Kent)

... to **Member:** C Heaney (Scotland)

... to **Associate Member:** C D Nicklin (Derby); S J Smith (Cambs)

... to **Student** T A Ijir (Hants); B J Magee (Northern Ireland); R J Merrall (Bedford);

Re-instatements

P K Afful (Lancs); J M Pollard (Scotland); D G W Stewart (Zimbabwe); G B Vaughan (Scotland)

Engineering Council registrations – congratulations to the following on inclusion on the register of professional engineers:

CEng R Earl (Beds); P R Mason (Herts); D B Williams (Warks)

IEng B Brewer (London); J T Loud (Warks)

Movements – members who have changed their address except where they remain in the same English county or, elsewhere, in the same country. We hope the move has proved beneficial.

C K Anornu (London to Belarus); A J Baldwin (Kenya to Latvia); P N Burt (Dorset to Tyne & Wear); A J Casebow (Hants to Uganda); C Champion (Oman to Hants); G P Higginson (Lancs to Essex); S M Hulangamuwa (Tyne & Wear to Sri Lanka); A J Landers (Gloucs to Shrops); R J Merrall (Dorset to Beds); R I K O'Neil Roe (Indonesia to Somerset); C W Plackett (Notts to Warks); R J Sims (Philippines to Somerset); S J Smith (Cambs to Shrops); J A C Steel (Tanzania to London); R W Taylor (Devon to Beds); K-I Weiner (Beds to Surrey); S G Williams (Beds to Wales); M A Zobisch (Kenya to Thailand)

A memorable occasion – President Brian Finney presents Bernice Bernard with her 50-year certificate at the Welsh Branch AGM.

Photo: S S M Davies

Excellence acknowledged

The Welsh Branch really had something to celebrate on the 9th March, the occasion of their AGM. Bernice Bernard, one of their respected members, was presented with her 50-year membership certificate by the President, Brian Finney. (see previous page for an appreciation of Bernice' career and membership record).

Brian was also called upon to salute the achievements of a young man at the opposite end of the career spectrum. David Jones was presented with a cheque and an inscribed tankard from the Branch to mark his outstanding performance in the City & Guilds 402 Mechanics Certificate course at the Coleg Powys.

David is a farmer's son at Garth, near Builth Wells, who is intent on diversifying into contracting/machinery repair. He completed the three year course in July last year and throughout he impressed both staff and fellow students with his enthusiasm and standard of work. John Bradshaw, the Welsh Branch Chairman, from who's report this appreciation of David was gleaned, said: ''Above all, David is a very honest, pleasant and hard-working young man and it is very gratifying that he has been acknowledged by the local Branch of the Institution of Agricultural Engineers.''

We wish David well in his ventures and hope that he fully capitalises on his skill and obvious talent to carve out a rewarding and prosperous business.

Feathers out of place !

In the last edition I wrongly attributed Dr J C Baker (see "Ruffled Feathers", p3) to Silsoe Research Institute. In fact, he is the contact for this topic at the University of Nottingham, and is not a member of this Institution to boot !

The SRI contact is Peter Kettlewell. Thank you Peter for pointing this out and my apologies for any problems it raised.

My apologies must also go to the Dr C J Baker FIAgrE in our membership who, as far as I'm aware, still resides in the beautiful isles of New Zealand. If any confusion has been created 'down under' by this article I regret it. *Ed*

Around the Wrekin

You'll recall the news from the last edition that **Ian Gedye** was to retire from his position as Head of Agricultural Engineering at Harper Adams Agricultural College. Behind his desk now sits **Andrew Landers**, late of the Royal Agricultural College. Congratulations, Andrew, you have entered an illustrious department and we're confident you will do it credit.

The Principal of Harper Adams and a member of this Institution, **Tony Harris**, is also retiring this year after many years of successfully leading that emporium of learning. Best wishes, Tony, for a long and happy retirement. I'm sure you won't be allowed to rest on your laurels – your experience in the world of education and training in agriculture is much too valuable for that, but like Ian before you, you can choose your assignments now that the pressure is off.

Expertise recognised

A few miles south and west of 'Harper' resides **John Boydell,** in Telford to be precise. John is Managing Director of a company called Custom Doors Ltd, making, as the name suggests, doors of all shapes and sizes, industrial and domestic. But it is not for this service that John has recently been honoured. Not only does he manage that business but he is also a consulting and investigating forensic engineer. In recognition of his expertise in this capacity he has recently been admitted to the register of qualified mediators of the British Academy of Experts – an accolade of the highest order in this field.

John Boydell inspecting the safety device on a Sedgwick 100-tonne brake press. The device forces the operator to use both hands to operate.

Project and environment management

William Hancox is taking a Master of Business Administration degree course at Strathclyde University which he is due to complete this September. After the course, William intends to continue with consultancy work specialising in project management, total quality management and environmental management.

William tells me that prior to moving to Scotland, he was working mostly on road construction projects overseas. During this time, he obtained membership of the Institution of Mechanical Engineers and CEng and, not having worked directly in agriculture for a number of years, he says he felt somehing of a fraud in maintaining membership of our Institution. However, now that he is to concentrate on project and environmental management, it is likely that overseas agricultural development will become a major source of his work.

I am pleased to hear that he is to continue to be a member of this Institution and I hope that this will prove to be of mutual benefit.

Water management

Arthur Thomasson tells me that since 1991, when he took early retirement from SSLRC at Silsoe Campus, life has been pleasantly occupied with part-time (about 50%) work in consultancy, editorial and liaison. He has been mainly concerned with soil and water and has worked for the NRA, for the EU in Europe and for the FAO. Arthur has recently moved to Pembroke where he has an acre of garden in a moist climate.This will give him an opportunity to exercise water management to a greater extent than previously in Hertfordshire.

Soil management

After teaching and research at the Universities of Kassel (Germany), Kumasi (Ghana) and Nairobi (Kenya) for the past 11 years, **Michael Zobisch** has now been seconded to the International Board for Soil Research and Management (IBSRAM) headquarters in Bangkok as research co-ordinator for the Land Development Network in Africa. Michael is in charge of IBSRAM's research into sustainable soil management practices, including moisture conservation, tillage, organic matter management, nutrient cycling and soil conservation.

IBSRAM is an international research centre financed and supported by a number of industrialised countries including the UK, Australia, Switzerland, Germany, France and the World Bank. It operates research networks in collaberation with national research institutions and universities. Emphasis is on applied and adaptive research with a considerable input from the national institutions.

Mission management

Alan Casebow and his wife have gone, on a voluntary basis, to Uganda to help with the management of a Mission hospital farm. It is expected that they will also be involved with rural development in the locality around Kiwoko, Luwero. I wish them well in this worthwhile task and would be grateful to hear of their experiences so that I can share them with our members.

Sweet success

S C Price has recently moved to the USA to establish a Training Division for F C Schaffer & Associates Inc. who are specialists in sugar processing and engineering. The Training Division is marketed as International Training Services and offers training courses in sugar technology and engineering.

Schaffer is specifically offering courses to meet the training needs of the international sugar industry. The company also conducts joint courses with Louisiana State University and the Audubon Sugar Institute. From 27 – 29 July 1994, Schaffer is organising a conference on Laser Technology for Land Development which will be marketed worldwide.

S C Price tells me that he has worked overseas for 28 years covering 12 different countries with assignments lasting for a few months to four years. In his present position as Director of Training Services for ITS, his main responsibilities are the development and implementation of the Schaffer annual training courses at the office in Baton Rouge, Louisiana. He is also acting as Team Leader/Training Specialist for a sugar factory rehabilitation and expansion project in Nigeria.

Full CV

I have had an interesting letter and a CV from **James Ramsay** running to six pages. James is now an independent environmental consultant trading as J Ramsay Associates and is based in Cambridge. His academic qualifications include a BSc (Hons) in Geography, a Postgraduate Diploma in Agricultural Engineering (Soil and Water) and an MSc in Forest Resources Management (Watershed Management) from the University of British Columbia, Canada. In addition to being a member of this Institution, James is also a member of the Institution of Environmental Sciences and is an Incorporated Engineer. He also speaks French, Sethotho and Nepali.

Married, with two children, James has worked in Bhutan, Canada, France, India, Jamaica, Kenya, Lesotho, Nepal, Pakistan, Qatar, Switzerland, Uganda and the UK. His areas of work cover environmental assessment and mitigation, watershed management, soil conservation, mine and quarry reclamation. James also has a special interest in protected areas, forest management, mountain and island environments, conservation strategies and sustainable development. Recently, he has been involved in the UK with trying to educate house-building and road-building clients that formal environmental assessments take more than two weeks and one discipline, and that quality is not a cost; it is a selling point.

Recent overseas work has included a compliance-monitoring job in St Lucia, and a month in Uganda looking at the impact of rehabilitating strategic transport links (including the potential effects on mountain gorillas of improved access and tourism). James is doing an increasing amount of work for IUCN — the World Conservation Union – on project design and technology transfer and he says that he is finding this the most rewarding.

Thank you James for your news and I wish you continued success.

Hungarian help

In the last edition of this journal mention was made of the offer by **Frederick Szirotta** of low-cost premises in Thetford, Norfolk.

In the seventies, Frederick managed an agricultural machinery dealership in Suffolk and in 1976 he joined International Harvester at Doncaster. When the Doncaster Engineering Centre closed, he was transferred to the USA. Frederick worked as a project engineer and has designed and managed several transmission projects from conception to production.

Frederick is a native of Hungary and in 1992 he was invited by the Hungarian industry leaders to help reorganise the Hungarian agricultural machinery industry. At present he is working on a machinery sharing-supply scheme on similar principles to a preplanned co-operative short term lease. Part of these activities is to relocate some machine production to Hungary and to find partners in the USA and Western Europe. There should be opportunities for British manufacturers and Frederick would be pleased to help if any British manufacturers are interested.

Frederick expects to be in Hungary for most of the time until October and his telephone number is 36-1 - 1751-344. However, he is due to be in Thetford from 26 to 29 June when he can be contacted on Mr Alliban's phone (0482 764241).

Thank you Frederick for the information about yourself and for your kind offer to help any British manufacturer both in the UK at Thetford or in Hungary. I hope that some UK companies will take up this generous offer.

Write to Tony with your news ! His address is: 32 Beverley Crescent, Bedford, MK40 4BY. – *Ed.*

Engineering implications of the reduction of post-harvest chemicals

Chris Bishop outlines the options for reducing the use of post-harvest chemicals. With emphasis on the engineering inputs, he considers the possibilities of better ventilation; 'live controlled atmosphere'; tighter into-store grading; grain cooling; total fumigation; and in-line chemical application.

Although some additives – for example, ash – have been used for many years, the use of post-harvest chemicals has become widespread in the last twenty or thirty years. These agrochemicals have produced many benefits, have allowed a much larger range of produce to be available and have greatly reduced post-harvest losses. However, concern over the effects of chemical residues on people's health has resulted in great pressure to reduce or eliminate the application of chemicals to crops after harvest.

Post-harvest chemicals are used on a range of crops:

- to suppress sprouting (eg. in potatoes and onions),
- to reduce or eliminate insect activity (eg. in maize),
- to reduce or eliminate microbial activity (eg. in barley) and
- to enhance appearance (eg. waxing the skin of citrus).

The future for post-harvest chemicals

Four approaches to future use of post-harvest chemicals can be envisaged and their engineering implications are examined below:

1) Continuation of present practices

From an engineering perspective, a continuation of present practices would result in on-going development of present-day application techniques.

2) Total elimination of chemicals

This is, in many cases, the easiest option to administer, but it may mean a change in consumer buying habits. Four main possibilities can be identified:

(i) *Change to less susceptible varieties*

In certain cases, the use of post-harvest chemicals can be reduced or totally eliminated by changing the variety.

For instance, with processing potatoes, there is great interest in using new varieties which are less susceptible to dormancy break and therefore require less, or no, sprout suppressant.

(ii) *Reduce, or more closely control, the product temperature*

In many cases, the mean temperature over the storage period (be that hours or weeks) can be very different to the extremes of temperature experienced during that same period. Fig 1 (Holloway, 1990) shows temperature variation (Standard Deviation 1.58) in a typical processing potato store. Disease or insects which may be controlled at the target temperature rapidly increase at higher temperatures.

Fig 2 (Bishop, 1992) shows temperatures recorded in a ware potato store with closer temperature control (Standard Deviation 0.29) but also with a higher ventilation capacity than in Fig 1.

To maintain closer temperature control, both a more alert operator and a better ventilation system may be required. A higher airflow and more ducts and sensors would be needed in addition to a greater appreciation of what is actually happening in the store.

Although a considerable understanding has been developed of the general storage environment (Robinson, 1988; Holloway, 1990), there are still gaps in knowledge as to the factors influencing localised temperature and humidity conditions in large commercial stores. This is true both of bulk and box stores and is especially true of stores which are subjected to periodic (sometimes frequent) loading and/or unloading throughout the storage period.

Recent research by Bishop (1992), Bani (1993) and Stenning *et al* (1990), in apple and potato stores has revealed discrepancies between actual and target temperatures, a large variation of temperature with time and a difference of as much as 50% in the energy requirement of refrigeration systems.

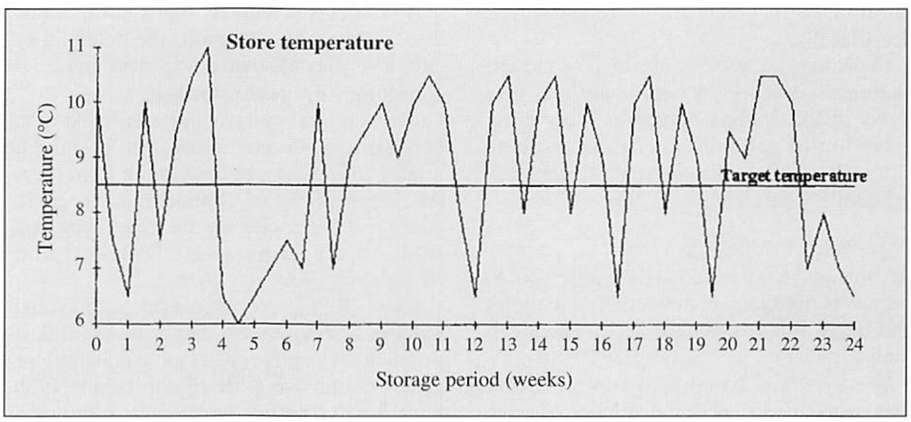


Fig 1. Store temperatures – Maris Piper & Pentland Dell. redrawn from Holloway (1990)

There are significant engineering challenges in meeting this commercial demand for improved quality of stored produce with the reduction or total elimination of post-harvest chemicals.

(iii) *Achieve better control of what is harvested and stored*

If diseased products could be removed during the harvesting process or before storage, the need for many post-harvest chemicals would be greatly reduced.

Normally, storage problems arise due to one diseased or damp fruit, vegetable or grain.

The developments of computer vision and robotic systems for produce handling now give the theoretical potential of removing all the externally diseased product prior to storage. Ultrasonics gives that same potential for internal disorders.

Quoting from Tillet (1993), "The general problem in the automatic grading of

---

Paper presented at the Herts & Essex Branch meeting of 27 January, 1994.

Dr C F H Bishop is Senior Lecturer in Agricultural Engineering at Writtle College, Essex.

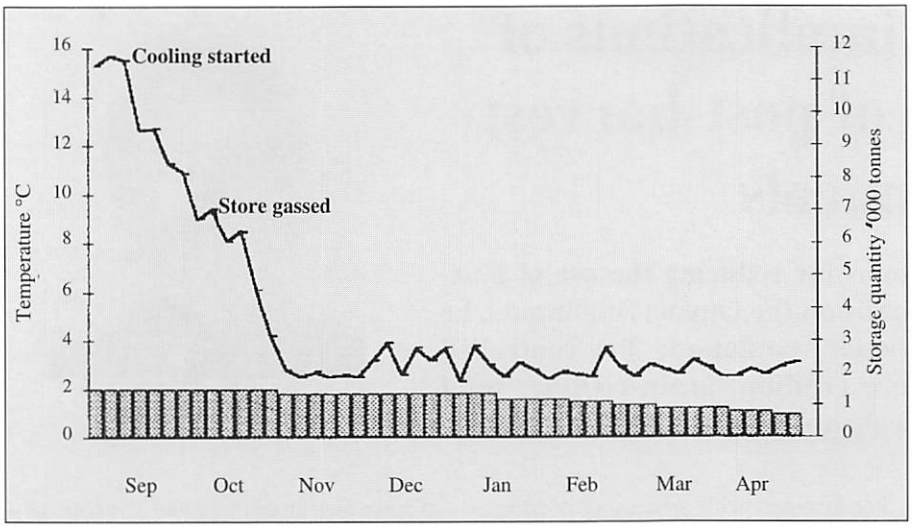


Fig 2. Temperature record – Refrigerated store (letterbox ventilated).

produce is the need to mimic the subjective decision of a human operator. It is not easy to quantify in a computer program the features that make an apple look attractive. For produce such as apples, a mark on the surface is bad if it is a blemish but not if it is on the stem or calyx, A level of intelligence is required to make the correct grading decisions.''.

Reducing the level of use of post-harvest chemicals could be a very beneficial side effect of the grading operation. Very close selection of product has been shown to eliminate the use of post-harvest chemicals in certain cases (Johnson, 1993).

(iv) *Control storage atmosphere*

At present, Controlled Atmosphere (CA) storage is used only commercially for apples and pears and is not necessarily chemical-free.

The system is based partly on the theory that many insects or fungi require oxygen. By lowering the store oxygen level, a reduction in insect infestation or microbial activity may follow. In extreme cases, stores have been intentionally put under anaerobic conditions for 24 hours (Dixon, 1993).

Over the last fifty years, considerable efforts has been put into investigating the possibilities of CA storage for other crops. A summary of some of these findings is given in Table 1.

– live CA

Future CA stores are likely to be designed, not as all-in/all-out stores as currently used for apples and pears, but as a stores where the product can be put in or taken out at will.

To the author's knowledge, there are currently only two stores – in Stockton, California – which allow for this facility, known as 'live CA'.

The two stores, of hemispherical shape, each hold around 8000t of product and are loaded and unloaded remotely using camera-controlled equipment.

During store loading, product bulk bins are placed in storage containers, each holding 24 bins. Storage containers are transported by conveyor to an intermediate chamber where the atmosphere is made similar to that of the store. The container is then moved into the store and located in position by a polar crane. The reverse process is used for unloading.

Although it is unlikely that a store of this size will become common, the potential of 'live CA' may open up new possibilities.

– chilling – for grain storage

Controlled atmosphere storage is unlikely to become a viable possibility with grain, but grain chilling may become more important. At present, 85% of commercial UK grain stores use insecticide on the store fabric and 68% on the grain itself (Prickett and Muggleton, 1990).

Grain chilling prevents insect activity and reduces both grain dry matter loss and dust problems. There is considerable potential for grain cooling using aeration in combination with a differential thermostat to achieve temperatures below 5°C.

The Home Grown Cereal Authority (HGCA) has developed a storage strategy to control insects without using pesticides by reducing temperatures with ambient aeration and monitoring pests with the use of traps. This work has been carried out on a farm scale level and has been developed further to include admixing on the grain surface to control upward migrating insects and for mite monitoring. (Anon, 1992)

– irradiation

Irradiation is another possible replacement of post-harvest chemicals but public resistance to this technique is even greater than it is to chemical usage.

– heat treatment

Heat treatments, although still at a research level, could also contribute.

Klein and Lurie (1992) conclude in their extensive review of heat treatments: ''although pre-storage heat treatments are a promising – alternative to chemical treatments, several aspects require continued research. Further research on Calcium (Ca) x temperature interactions will develop the potential for heat/Ca treatments to increase protection against pathological and physiological disorders. The possible synergistic benefits to be derived from combining heat treatments with other storage methods, such as modified atmosphere (MA) packaging, also bear investigation.''

3) Use chemicals effectively.

Clearly, it is in everyone's interest to ensure that chemicals are used effectively, However, in many cases, there are restraints beyond the operator's control as illustrated in the following examples:

(i) *In-store fumigation*

A number of crops receive chemical application in-store for various reasons such as sprout suppression in potatoes, insect reduction in grain and fungi control in table grapes.

One of the difficulties experienced with in-store fumigation is the high level of variability of chemical concentration application within the stored product. This results in higher chemical levels being used purely to ensure that all product receives an adequate dosage.

Following trials on sulphur fumigation of table grapes (Luvisi *et al*, 1992), the following seven factors were identified as being associated with dosage variation:

Table 1. Summary of recommended CA or MA conditions for selected products.

Commodity	*Temp range °C*	O_2 *%*	CO_2 *%*	*Remarks*
Apples	0-5	1-3	1-5	About 50% of production under CA
Apricots	0-5	2-3	3-5	No commercial use
Avocado	5-13	2-5	3-10	Limited commercial use
Brussel sprouts	0-5	1-2	5-7	No commercial use
Cabbage	0-5	2-5	3-6	Some commercial use for long term cultivars
Carrots	0-5	none		
Lemons	10-15	5-10	0-10	No commercial use
Mushrooms	0-5	air	10-15	Limited commercial use
Strawberries	0-5	5-10	15-20	Increasing use during transport
Potatoes	0-5	none		

Data selected from Kader A A *et al* Post-harvest Technology of Horticultural Crops. Berkeley, CA, University of California 1992 Special Publication 3311.

- Design and type of box
- Passive or active ventilation through box
- Air velocity
- Position of pallet in the store
- Position of the box within the pallet
- Store room material
- Humidity and free moisture present.

The traditional method of table grape fumigation uses high levels every seven days of sulphur dioxide (2,500 - 5,000 ppm) with the store then vented after half an hour.

The total utilisation method differs from the traditional system in that the sulphur dioxide applied is in balance with the amount of sulphur dioxide absorbed by the fruit, the boxes and the room itself. The fumigation is prolonged beyond half an hour and if sulphur dioxide concentration at the end is more than 2ppm subsequent doses can be decreased or the fumigation interval time increased.

(ii) *In-line chemical application.*

The objective of in-line chemical application is to completely cover the product surface to achieve effective disease control or total surface enhancement. Normally, this is accomplished by passing the rotating crop under an applicator nozzle.

Correct calibration, a soil-free crop, suitable shrouding for the liquid applicator and a close relationship between the crop throughput and the chemical application rate (normally a consistent, known, crop throughput against an even application rate) are important factors which affect application uniformity.

The Potato Treater group of the British Crop Protection Council (BCPC) has been closely involved with directing work which enables a closer understanding of the problems and possible solutions in this area.

In addition to producing a check list of good practice (Anon, 1993), work (both in progress and completed) at Writtle College in conjunction with BCPC has highlighted some of the areas of possible discrepancy.

The coefficient of friction of wet or dry, dirty or clean tubers varies by nearly 50%. This affects the number of tuber rotations under the nozzle and in extreme cases, the tuber may not rotate at all. At present, work is also being undertaken to ascertain the optimum number of rotations and rotating speed under the applicator (Fig 1).

Evidence, from video recordings, has shown that there is often an edge effect exhibited by the roller table which results in the speed of forward travel and rotation being different for the product in the centre of the roller table as opposed to that at the edge.

These factors (varying with crop size) all work against even application which therefore means that a higher rate of chemical is required to ensure that all parts receive sufficient coverage and hence guarantee disease control.

There is still a considerable amount of engineering input required to solve these problems and work is ongoing at Writtle College and the SAC (Bowen, 1993).

4) Use naturally occurring chemicals

The use of naturally occurring chemicals may result in the same application considerations as for synthetically produced ones, with similar engineering applications.

Results can be dramatic. For example, in East Africa, potato production was very much restricted by the prevalence of the potato moth which caused high storage losses. However, the problem was solved by placing a small amount (one branch per 50kg) of a local weed, *Lantana camara*, in the store with the potatoes (Taylor-Hunt, 1992). The precise reason for the success of this technique is unclear.

Conclusion

With increasing public concern over the use of post-harvest chemicals, there will be more pressure to produce alternative solutions.

Solutions will include closer control of what is involved in the storage process, emphasising the need for more accurate information on the actual state of the product in question and the atmosphere in which it is stored.

For everyone's benefit, it is important that the engineer realises the potential engineering implications and is closely involved in finding a solution to these problems.

References

Anon (1992). Integrated pest control strategy for stored grain. *HGCA Report No 57.*

Anon (1993). Roller table efficacy checklist for chemical application. British Crop Protection Council/Writtle College *Writtle College Information Sheet.*

Bani R J (1993). Prediction of the environment in commercial fruit and vegetable stores. *PhD Thesis*, Silsoe College.

Bishop C F H (1992). Energy efficiency of cooling systems for potato storage. *PhD Thesis*, Silsoe College.

Bowen S (1993). Developing a seed fungicide strategy. *SAC Potato News*, Nov, p.4-5.

Dixon J (1993). Private Communication.

Holloway S M B (1990). Monitoring of temperature and related conditions in commercial potato stores. *MPhil Thesis*, Silsoe College.

Johnson D S (1993). Storage of UK apples without post-harvest chemical treatment – the problem and possible solutions. *3rd COST Workshop on post-harvest treatment of fruit and vegetables*, Milan, Italy.

Klein J D, Lurie S (1992). Heat treatment for improved post-harvest quality of horticultural crops. *Hort. Technol.* 2(3) p.316-320.

Luvisi D A, Shorey H H, Smilanick J L, Thompson J F, Gump B H, Knutson J (1992). Sulphur Dioxide fumigation of table grapes. *Publication 1932*, Univ. California, Div. Agric. and Nat. Resources.

Prickett A J, Muggleton J M (Eds) (1990). Commercial grain stores, 1988/89, England and Wales: Pest incidence and storage practice. *HGCA Project* Rep. No 29.

Robinson J. (1988). Free convective airflow in fruit stores. *PhD Thesis*, Silsoe College.

Stenning B C, Bishop C F H, Holloway S M B, Robinson J (1990). Interpretation of temperature records from distributed positions in commercial potato stores. *Proc. Eur. Ass. Potato Res. 11th Triennial Conf.* p.505-506.

Taylor-Hunt G L (1992). Innovative cooling methods for low-cost crop storage in the hot humid tropics. MPhil Thesis. Silsoe College.

Tillet R (1993). Developments in computer vision and robotic systems for produce handling. *Technol. advances in the transport, handling and storage of fresh horticultural produce Conf.* NRI, Chatham, Kent.

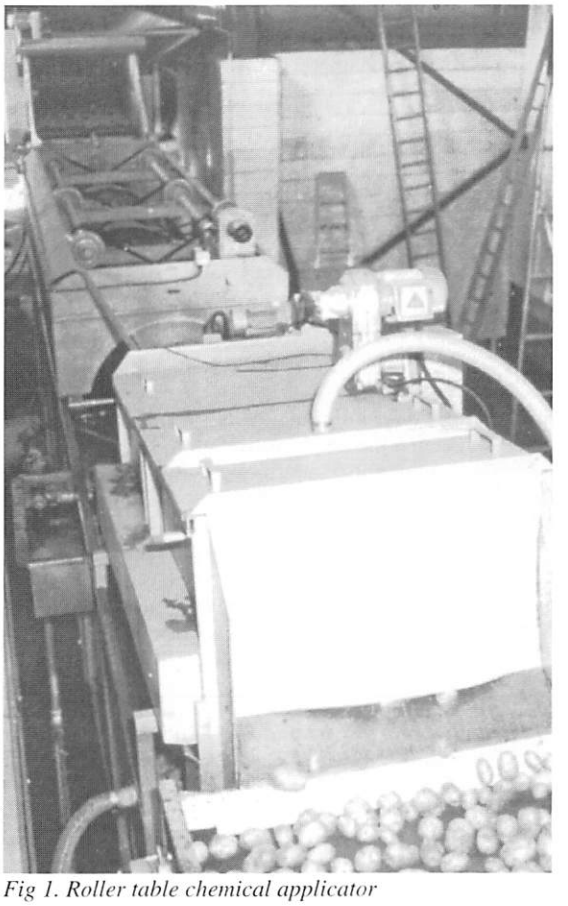


Fig 1. Roller table chemical applicator

National irrigation surveys

Chris Stansfield updates his earlier reports* on the irrigation scene in England and Wales.

Since 1955 MAFF (Ministry of Agriculture, Fisheries and Food) has carried out a series of 15 irrigation surveys for England and Wales. These have provided a variety of information for planning purposes and are used by both farming and water industries.

The real impetus for the present series of surveys arose following the publication of Sir Nigel Strutt's report "Water for Agriculture: Future Needs" in 1980. For the first time, one definitive document detailed current practices for irrigation, stock drinking, washing and processing and domestic consumption on farms. The report also made water consumption forecasts based on the economic outlook for agriculture at that time.

Although in some quarters the water consumption forecasts presented in the Strutt Report have subsequently been criticised because they were too optimistic, it should be recognised that they were made on the assumption that trends in agricultural output based on maximising production would continue. This assumption exaggerated the need for irrigation, but nevertheless, if notice had been taken of these forecasts and resources had been allocated accordingly, then the problems that farmers have experienced in the drought years from 1989 onwards with compulsory and voluntary restrictions instigated by the National Rivers Authority (NRA) would probably have been avoided.

Previous reports by Chris Stansfield on the MAFF Irrigation Surveys – The Agricultural Engineer **44 3 95-97 and **47** 1 6-8.*

C B Stansfield is Manager of the Land Development Centre, Gleadthorpe Grange, Mansfield, Notts.

The MAFF Surveys

The MAFF surveys are carried out to provide information for water resource planners to take account of the agricultural water requirements in strategic development plans over 25-30 years. The surveys are based on the irrigation of outdoor crops as distinct from glasshouse crops and are aimed at finding out how much water is used, where it comes from and on what crops it is used.

The survey is conducted amongst all those who are known to irrigate and asks a series of questions on current irrigation usage. This is achieved by a user friendly questionnaire listing the main irrigated crops. Information is collected and aggregated so that data from individual holdings cannot be identified.

Potatoes and vegetables are the most important crops for irrigation

Data from the previous five surveys are presented in Table 1. It can be seen that the area irrigated varies from approximately 0.75 to 1.5% of the total cropped area of over 10 million hectares in England and Wales.

The most important crops irrigated are potatoes which in 1992 made up half of the area irrigated; sugar beet and vegetables, which now account for 20% of the irrigated areas.

Table 1. Actual areas of outdoor crops irrigated and volume of water applied.

	Crop area, ha					*Water volume, '000m³*				
	1982	*1984*	*1987*	*1990*	*1992*	*1982*	*1984*	*1987*	*1990*	*1992*
Potatoes: harvested by 31 July	8050	7720	5360	8510	8180	4680	4920	2350	6770	5590
harvested after 31 July	22810	34610	29520	43490	45290	15280	32730	14700	51170	38520
Sugar beet	15770	25500	10100	27710	10520	8260	17370	3430	20320	4860
Orchard fruit	3100	3250	1330	3320	2280	2180	2430	550	2930	1220
Small fruit	3610	3560	2230	3470	2750	1890	2660	970	3180	2000
Vegetables for human consumption	14810	17460	11040	25250	20200	6830	11390	4640	18450	12180
Grass	16440	18940	6970	15970	7240	10030	13550	3550	13100	4280
Cereals	14800	24700	7510	28100	7160	5040	8300	2160	11830	2260
Other crops grown in the open	4100	4890	2440	8650	4320	1020	4030	1270	6040	4160
TOTALS	103490	140600	76520	164460	107940	55210	97370	33630	133790	75070

In future it is the customer via the supermarket buyers who will dictate quality requirements and potatoes and vegetables will continue to be the most important crops irrigated.

The seasonal difference, highlighted in Fig 1, is created by the amount and distribution of normal rainfall and is quite marked – 1990 being the year with the largest irrigated area. There are also differences throughout the year and while both 1990 and 1992 seasons were dry early on, the rainfall in July of 1992 meant that the area of sugar beet irrigated was considerably reduced compared with the drier 1990.

A similar seasonal pattern is seen in figures for volume of water applied and it is this seasonal variation that makes planning difficult.

Irrigation requirement can be up to half total daily water usage

Taking the country as a whole, irrigation water requirements are quite small, compared to industrial and domestic usage. In fact irrigation consumes less than 1% of the total amount of water used on a daily basis. This does, however, hide marked differences between the different parts of the country.

The highest demand for outdoor irrigation is in the eastern parts of England where it can represent nearly half the daily water requirements in drought periods.

Irrigation is generally applied from April to September with most applied in June, July and August. It is this high demand in a short period when effective rainfall is lowest and other uses for water are at their maximum that creates problems in water resource management.

Sources of irrigation water – increasingly from deep boreholes

Farmers were asked to specify their water source. Table 2 gives details.

The main trend over the 10 year period is for the reliance on rivers, stream or other watercourses to diminish and the amount taken from boreholes to increase gradually. This could be attributed to less reliance being placed on surface water sources which have been under threat from NRA actions and also for extra pumping from existing boreholes.

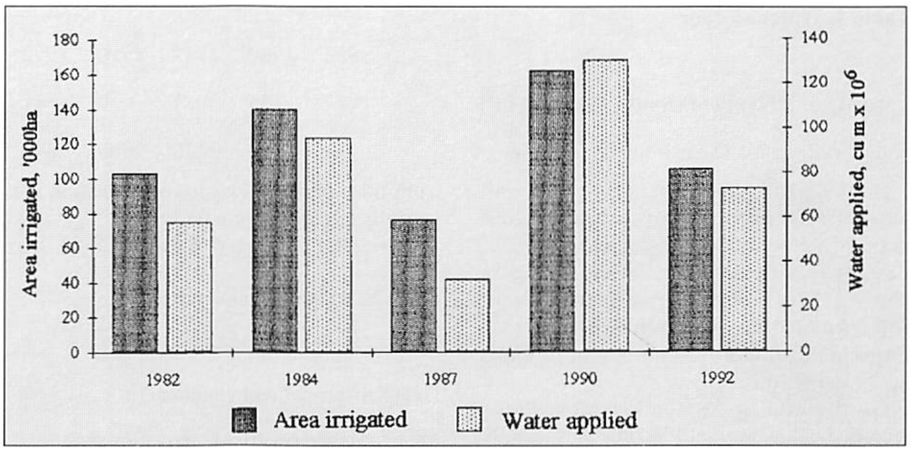


Fig 1. Seasonal differences in area irrigated and volume of irrigation water applied.

How much water would be used in a dry year?

One leading question asked is for farmers to specify the area of crops and amount of water that they would apply in a dry year assuming that there was an adequate water supply. The figures for their estimates given in each of the years 1984, 1990 and 1992 are presented in Table 3.

It is interesting to compare these figures with a computer simulation carried out by Bailey and Minhinick (1989). This examined cropping, soil and climatic data and indicated that, in the driest year, 237 million cubic metres of water would be needed. This compares with the farmer forecast of 234 million cubic metres for 1992.

Table 2. Sources of water and volume used.

Water source	*Water applied ('000m³)*									
	1982		*1984*		*1987*		*1990*		*1992*	
	Volume	*%*	*Volume*	*%*	*Volume*	*%*	*Volume*	*%*	*Volume*	*%*
River, stream or other watercourse	27520	50	47840	49	16000	48	62330	47	34310	46
Spring rising on holding	2580	5	4370	4	1580	5	5360	4	2830	4
Well	2560	5	3210	3	1130	3	3230	2	1890	3
Deep borehole	11540	21	24840	26	9090	27	41950	31	23750	32
Pond or lake	5800	11	8470	9	2870	9	9570	7	6570	9
Gravel or clay working	1070	1	1260	1	380	1	2170	2	940	1
Public supply main	2040	4	3840	4	1100	3	3860	3	2620	3
Other source	1830	3	3540	4	1470	4	5330	4	2160	3
Total volume of water applied	54940	100	97730	100	33620	100	133790	100	75070	100

Water storage

It is also interesting to note the amount of water stored in reservoirs and tanks. By the time of the 1992 survey, it is seen that this storage has virtually doubled from the 1982 figure (Table 4).

MAFF, NRA and the farming organisations have all been advocating the construction of additional storage facilities by farmers and their success in promoting this is amply demonstrated by these figures.

Farmers with their own storage are independent of third party activities likely to affect direct abstractions. This is vitally important where high value and consequently, high risk, crops are being grown.

The number of earth and earth-lined reservoirs has fluctuated over the years but has increased in 1992 to 2,840 compared with 2,700 in 1984. In between this period the number fell. This is thought to be because some larger reservoirs have been decommissioned as a result of implementing the 1976 Reservoirs Act and more smaller ones have been constructed. It is also possible, due to changes in farm policy, that some former irrigation reservoirs are now used for other purposes such as fishing.

Irrigation equipment

Questions are asked in the survey about the type of equipment and techniques used on farms. The move towards self-propelled irrigators is clearly shown in Table 5. The increase of 28% in the last 8 years highlights the labour saving benefits of using automatic equipment.

The area of trickle irrigation has seen a slight upsurge in 1992 and this is most probably as a result of growers taking advantage of more accurate applications available by this technique. The area under frost protection has continued to decline and is now only 1,890 ha in total.

Table 3. Estimates of likely irrigation requirements in a dry year.

	Year of estimate		
	1984	*1990*	*1992*
Area of crops likely to be irrigated (ha)	189310	202620	218550
Volume of water likely to be applied ('000,000m³)	167	179	234
Depth of water likely to be applied (mm)	90	90	110

1992 weather conditions

A comparison of Potential Soil Moisture Deficit (PSMD) compared with the average for the 1961 – 1990 period is shown in Table 6. All values have been calculated for grassland using MORECS grid square values.

Table 4. Water storage.

	1982	1984	1987	1990	1992
Capacity of all types of storage ('000,000m^3)	22	33	37	37	41
Number of earth and earth-lined reservoirs	na	2700	2420	2580	2840

In 1992, the months of April, May and particularly June tended to have below normal rainfall in East Anglia and the South East so PSMD values there were initially above normal. However, wet weather in July, August and September right across England was more than sufficient to make up the earlier differences.

By the end of September most areas recorded below normal PSMD's – especially so in parts of the south Midlands. In the Cambridge area the PSMD was marginally above normal.

The Future

In the driest year, up to 240 million cubic metres of water are needed. Supplies cannot meet this demand and although the NRA will take this into account in developing their future strategy undoubtedly much of the requirement will need to be met from storage. Whether this should be from an individual farm reservoir, from shared farm reservoirs or from third party reservoirs is a question not yet fully explored nor answered.

How much water will be needed? The NRA has commissioned a study on future water requirements for agriculture to the year 2021. This should provide the basis for reliable forecasting.

What is clear is that the demands from consumers for precise quality produce require farmers to have a regular, uninterrupted supply of irrigation water. Farmers cannot operate economically with the constant threat of shut down in water supply.

It is estimated that if all irrigation ceased the loss of output would amount to a value of some £433 million. This shortfall in supply would be filled by our overseas competitors – thereby widening the current trade gap.

Table 5. Irrigation equipment.

	1984	1987	1990	1992
Total self-propelled irrigators	4770	4880	5550	6120
Area equipped for trickle irrigation (ha)	1550	1330	1420	1970
Area equipped for frost protection (ha)	2080	2710	2170	1890

Climate change

While the statisticians argue about the magnitude of change it is clear that a temperature rise has occurred. The effect of this is shown in an example which compares the departure of summer rainfall for Shawbury in Shropshire over the last 24 years compared with the 1961-90 average (Fig 2 next page) In this period, 60% of summers were drier than average.

The temperature rise will also effect irrigation requirements. Current estimates suggest a 1.5°C rise in average temperatures in the next 25 years and a similar rise in the following 25 years. This will mean a shift of cropping north and westwards and lead to the introduction of new crops such as navy and soya beans, and an extension of grain maize. This change in cropping coupled with less effective summer rainfall will increase the demand for irrigation.

Table 6. Weather conditions compared.

Potential Soil Moisture Deficit (PSMD), mm

		April	*May*	*June*	*July*	*Aug*	*Sept*
Cambridge	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
	1992	15	72	125	137	177	128
	Average	20	55	90	137	155	120
Oxford	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
	1992	9	15	75	59	59	23
	Average	15	42	71	115	133	132
Maidstone	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
	1992	0	56	128	140	133	119
	Average	10	42	72	113	145	142
Nottingham	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
	1992	20	66	98	85	87	66
	Average	15	40	65	96	1107	100

References

Bailey R J, Minhinick J (1989). The Agricultural Requirement for Irrigation Water *JIWEM* October.

MAFF (1993). Survey of Irrigation of Outdoor Crops 1992 England and Wales *Statistics Notice CSS 6375.*

MAFF (1991). Survey of Irrigation of Outdoor Crops in 1990 *Statistics Notice 157/90.*

MAFF (1988). Irrigation of Outdoor Crops: England and Wales Special Enquiry 1987 Season *Statistics Notice 132/88.*

MAFF (1985). Irrigation of Outdoor Crops: England and Wales Special Enquiry 1984 season *Statistics Notice 148/86.*

MAFF (1983). Irrigation of Outdoor Crops: England and Wales Special Enquiry 1982 season *Statistics Notice 217/83.*

Stansfield C B (1992). Irrigation Surveys by ADAS – *Agricultural Engineer* 47.1.

Stansfield C B (1989). Irrigation Surveys by ADAS - Agricultural Engineer 44.3.

Strutt *et al* (1980). Water for Agriculture: Future Needs R*eport of the Advisory Council for Agriculture and Horticulture in England and Wales* HMSO.

Woodley R, Stansfield C B (1986). MAFF 1985 Irrigation Survey *Irrigation News* 9.

concluded at foot of next page

Protecting the Rural Environment

The 35th Scottish Branch Annual Conference

Perth, 23rd February, 1994

Public awareness of the damage being caused to the planet has crystalised into a growing realisation that unhindered pollution cannot be allowed to continue and that economic growth must be tempered with the concept of sustainability.

Environmental legislation

Donald A Reid, of the solicitors and notaries, Morton Fraser Milligan, presented the opening paper on '*Environmental Legislation*', an increasingly important topic with environmental protection being one of the major social and political issues of the decade.

There are two principal methods of attempting to halt or at least greatly reduce environmental damage.

The 'big stick' approach of setting standards and enforcing these with the criminal legal system is the traditional method and works relatively well provided there is adequate policing of regulations and the courts are prepared to hand down exemplary fines as a disincentive to ignore compliance.

Another approach currently being promoted particularly by the European Commission in an attempt to implement the much vaunted 'polluter pays' principle is the operation of the market and the intervention by Government with various economic incentives.

It is, however, legislation and regulations which constitute the main driving force behind current policy on environmental protect-ion, particularly since the passing of the Environ-mental Protection Act in 1990.

There have been statutes and common law provisions to restrain pollution of the environment for centuries but it is really only with the current focus on environmental problems on an increasingly global scale that environmental law has developed as an identifiable specialism in legal practice.

Eighty delegates, including representatives of River Purification Boards, Waste Disposal companies, Agricultural Advisers, Enforcement Bodies and Educationalists attended an informative and interesting conference which explored aspects of waste treatment and disposal in the light of future environmental legislation.
The smooth running of the conference reflects the hard work put in by its convener, Denis Welstead.

Attention now focussed on farmers and other land users

Industry has for long been seen as a major culprit in the environmental debate, but increasingly, attention is being turned to farmers and others who derive their livelihood from the management of agricultural land, forestry and associated activities.

Farmers have been accustomed to using highly toxic substances with considerable potential to cause damage but there has been relatively little control over the disposal of these materials or other waste products. In addition, with the current emphasis on restricting production from farms, attention is being given to the management for conservation purposes of set-aside land and to financial inducements to use land in more environmentally acceptable ways, and for these reasons environmental laws are increasingly impinging on aspects of agricultural business hitherto exempt from control.

Current statutory controls

Traditionally, environ-mental legislation has targeted the three media of air, water and land separately (eg. the Clean Air Acts and the Water (Prevention of Pollution) Acts).

The Control of Pollution Act 1974 was the first attempt to bring control under one statute and this process has been further developed by the Environmental Protection Act 1990, which for the first time introduces the concept of

National irrigation surveys *concluded from previous page*

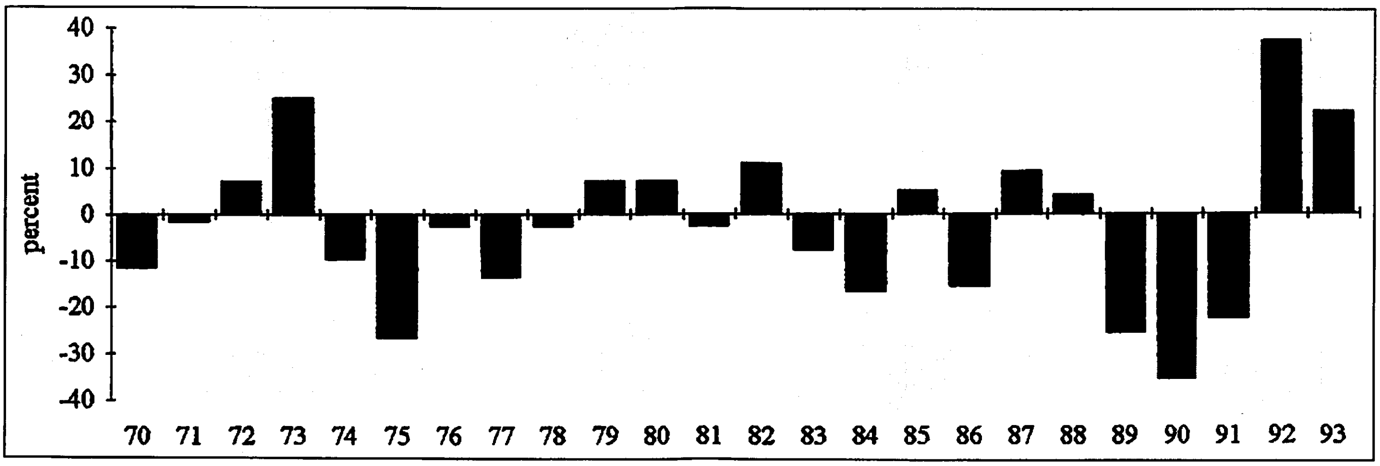


Fig 2. Percentage variation from the 1961-1990 summer average rainfall (325mm) at Shawbury, Shropshire.

integrated pollution control designed to ensure that as far as possible all-round protection is achieved by looking at pollution on a "cross-media" basis. Integrated pollution control, however, relates only to certain 'prescribed processes', few of which are involved in agricultural activities.

There are, however, media specific statutes which still apply. For water pollution, the Water Act 1989 confirms the principal offence of permitting poisonous, noxious or polluting matter to enter controlled waters without a discharge consent and the Public Health (Scotland) Act 1897 still provides important remedies to local authorities to clean up toxic substances on land.

The whole issue of contaminated land is one of great topical interest particularly in respect of the building and constructing industry and the Government is currently conducting a review into future controls over such land.

There is little doubt that the immediate future will see continuing pressure for increasing regulation and tighter standards for environmental emissions which could result in further European Directives and National regulations.

New emphasis on 'management of waste'

From 1st May 1994, a completely new regime of waste licensing will be introduced under Part II of the Environmental Protection Act. The emphasis will, thereafter, be on the management of waste as distinct from its disposal and all persons involved in the deposit, treatment, storage and disposal of waste will require a licence to operate.

Until now, waste arising from premises used for agriculture has been exempted from the definition of 'controlled waste' for which a licence is required. Under new regulations, yet to be published, it is possible that some hitherto exempted agricultural waste may be included.

Regulatory agencies

As with the laws which they are tasked with monitoring and enforcing, regulatory agencies have traditionally dealt with one medium only. However, the Scottish Environmental Protection Agency will in future combine the activities of such bodies as the River Purification Boards, Her Majesty's Industrial Pollution Inspectorate and District Councils in their capacity as waste regulatory bodies.

Confirmation of the new Agency's development was included as a paving measure in the Queen's Speech last November.

Compensation for damage

In an attempt to implement the 'polluter pays' principle, increasing attention is being paid to making polluters compensate those who suffer damage as a result of their activities. Common law has always provided the possibility of a damage claim and some Regulatory Agencies (in particular Local Authorities) have considerable powers to require a polluter to clean up the results of illegal activities.

The European Commission sees liability as a form of economic incentive and is currently considering the possibility of introducing a harmonised system of strict liability for environmental damage throughout the 12 Member States. This would have very far-reaching consequences.

Agricultural activities subject to pollution control

The impact on the environment of agricultural operations will, in many cases, be obvious. In others (such as diffuse water pollution from agricultural run off), the end result may be less apparent.

Pesticides and fertilisers are both used extensively by many operators in the agricultural sector. Both have great benefit to agriculture and forestry but their advantages have to be weighted against the risks. Hitherto, the risks were seen as falling mainly on the health of operators and those living closest to the site of application, but these risks are now recognised as having considerable potential to damage the environment itself.

— pesticides

The principal statutory controls on pesticides are under the Food and Environment Protection Act 1985 and the derivative Control of Pesticides Regulations 1986. In addition there are statutory Codes of practice which also apply. The Control of Pollution Act 1974 controls disposal of waste pesticides.

— fertilisers

Fertilisers tend not to be subject to the same constraints as their purpose is to stimulate growth. Nevertheless, over-enthusiastic application can give rise to problems when nutrient losses migrate to water courses either by direct run-off or by leaching to groundwater systems. Legal controls, therefore, tend to concentrate on the quality of receiving waters and in this connection the Water Supply (Water Quality) (Scotland) Regulations 1990 made under the Control of Pollution Act 1974 are of particular importance.

— other agencies

Other farming operations are the cause of many water pollution incidents and many prosecutions arise from the careless use or disposal of sheep dip. There is a clear risk of prosecution under the Control of Pollution Act for releasing poisonous or noxious substances into controlled waters if proper measures for the use and disposal of sheep dips are not taken.

Silage effluent is even more damaging. Given the number of silos in Scotland, the risk of effluent getting into streams or the groundwater system is very high. The Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) Regulations 1991 were introduced to lay down standards for the construction and positioning of new and reconstructed silos.

Other aspects of land management which are the subject of environmental control include forestry spraying, spreading of sewage sludge, the disposal of fallen livestock, stubble burning and even such mundane operations as the burning of redundant fertiliser bags, stack covers, etc.

Avoid the offence

Generally, the law recognises that if a potential accused has taken all reasonable steps to avoid committing an offence this will go a long way towards providing a defence. Recognising this, the Scottish Office issued a Code of Practice on the Prevention of Environmental Pollution from Agricultural activity, designed as a practical guide for all those involved in agricultural activities and highlighting management practices which should strike a balance between reducing the risk of pollution occurring while enabling traditional agricultural practice to continue.

Future developments

Some areas of farming activity are reducing in severity as far as environmental pollution is concerned (particularly moves towards more use of organic fertilisers and less toxic pesticides). Other areas will increasingly become targets for regulation.

Scotland, unlike England, relies to a very small extent at present on groundwater systems but it is likely that increasing use will be made of boreholes to tap underground supplies. Many of Scotland's native industries are particularly sensitive to the maintenance of continuing reliable water supplies and one of the biggest threats to this source is diffuse pollution caused by run-off from agricultural and forestry land.

We have not yet seen any 'mega fines' for environmental pollution in Scotland. This could well change.

The Environmental Protection Act has already greatly increased the level of fines that can be imposed for a first offence and the Crown Office is currently engaged on a review of the prosecuting authorities' approach to environmental cases.

The trend at European level is towards bringing into the liability net more agricultural activities. Ignorance of the law is, of course, no excuse, but certainly awareness of current controls and pending development as far as agricultural activities are concerned will increasingly become a factor which the farming industry will have to consider.

Water pollution will remain a major area of attention giving increasing concern at international level for the protection of this essential resource.

Control of water pollution

David Holloway, Chief Pollution Prevention Officer of the Forth River Purification Board, spoke on *Water Pollution* and described briefly with particular reference to Scotland, how this is being achieved. While there are many similarities in the problems and the regulation and legislation which exists in England/Wales, there are some fundamental differences which set Scotland apart.

Early legislation proved ineffective and it was not until the implementation of the Rivers (Prevention of Pollution) Act 1951 and its Scottish equivalent, followed by the similarly named 1961 Act (1965 in Scotland) that effective control could be applied. The control powers have subsequently been extended by the implementation of the Control of Pollution Act (COPA) 1974 to include discharges into/onto underground waters and coastal waters up to the 3 mile limit and of surface water into a watercourse. Further powers have been provided to the purification authorities by incorporation of COPA into the Water Act 1989.

— River Purification Authorities

In order to give effect to the Rivers (Prevention of Pollution) legislation, River Purification Authorities, were established, which currently consist of seven River Purification Boards (RPBs) and three Island Councils. Their principal duties are to pursue the improvement of poor quality water whilst maintaining existing high quality waters within their catchments using the control and enforcement procedures provided by statute.

— The 'Polluter pays' principle

Financial resources have traditionally been obtained by requisition from the regional councils and hence through the community charge/council tax scheme. The implementation of the Water Act 1989 provided the Secretary of State with the opportunity to require the RPAs to introduce an approved scheme of charges whereby dischargers who impacted the Board's workload met the cost of that workload — the 'polluter pays' principle. Costs are recoverable for the processing of applications for consent and any subsequent monitoring carried out relevant to that discharge. In this way some 20% of the RPAs' revenue expenditure is met directly by the dischargers.

The high organic strength and toxic nature of many agricultural wastes, together with the frequency of pollution incidents of an agricultural origin, have resulted in the deterioration of many of the nation's rivers. Within the Forth Board, for example, 35km of freshwater are downgraded to an unacceptable level as a consequence of agricultural activity.

The Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) Regulations 1991 was the response by central government, whilst continuing to provide grant aid to the agricultural industry for pollution prevention improvement works, to specify standards of construction and operation of farm waste collection and disposal systems and of oil storage.

All of the RPAs would welcome parallel regulations controlling the storage and use of oil/chemicals on industrial sites. Negotiations are ongoing with central government, but progress is slow.

— balancing benefits against costs

Alongside the pressure for setting tighter standards there is also a clear move to examine the environmental benefit of any such tighter standards and to balance this against the costs involved.

One example of this trend is the Urban Waste Water Treatment Directive which requires sewerage undertakers to provide treatment of sewage from relevant communities to common standards.

It is estimated that the cost of implementing this directive in the UK could be £8-10 billion before 2005, much of this directed towards providing treatment for coastal communities.

One knock-on effect of this improved treatment will be the production of greatly increased quantities of sewage sludge with inherent difficulties with its disposal.

The sewerage undertakers are developing strategies for the disposal of this sludge ranging from composting to incineration. Tayside region anticipate that all of their sludge can be disposed of to agricultural land. This will require close liaison with Environmental Health and RPB staff to ensure minimisation of environmental risk.

— the Scottish Environment Protection Agency (SEPA)

The major development in the immediate future is the proposed formation of the Scottish Environment Protection Agency (SEPA), timetabled to come into being in April 1996. This agency is likely to amalgamate the functions of the RPAs with those of Her Majesty's Industrial Pollution Inspectorate, the Hazardous Waste Inspectorate and the waste disposal and atmospheric emission regulatory functions of the district councils.

The organisation and structure of the proposed agency is currently under consideration and a 'paving bill' is currently before parliament which will allow the establishment of a shadow agency, possibly sometime in 1995, to ensure a seamless transmission of function to the new agency. Whilst this will provide industry in particular with a single agency with which to deal – so called 'one-stop shopping' – the great fear is the loss of local acceptability with the transfer of policy making to a centralised function.

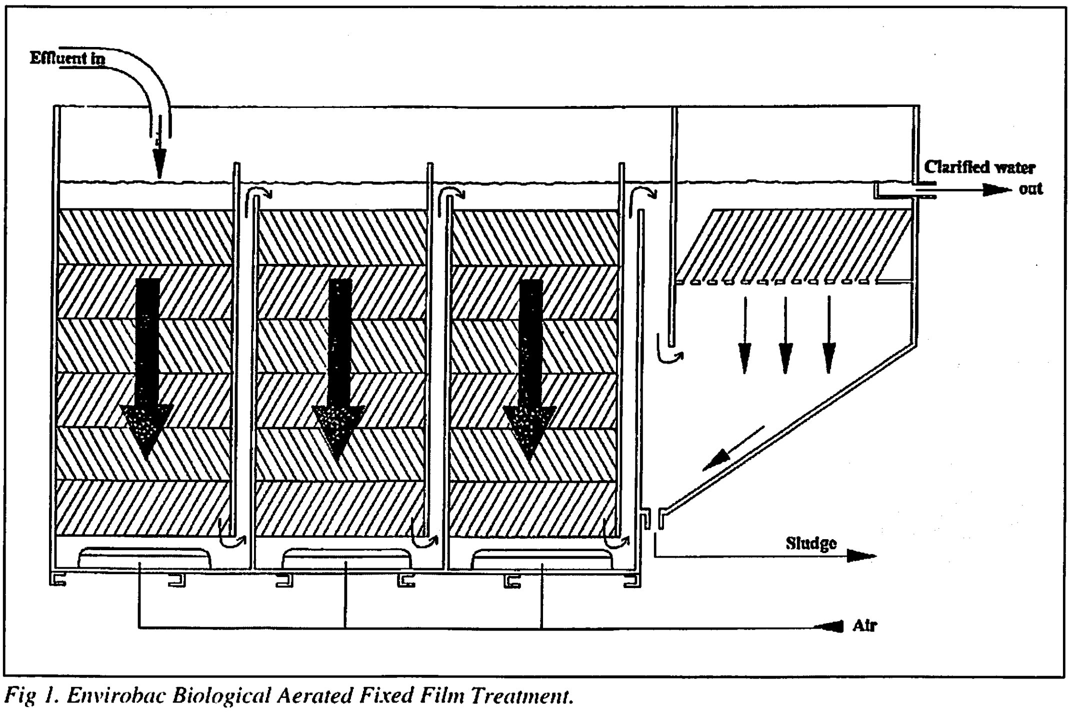


Fig 1. Envirobac Biological Aerated Fixed Film Treatment.

Until recently, the United Kingdom had perceived sludge in terms of a waste disposal problem. That view is rapidly changing. Waste is now being seen as a production material.

Processing of waste

Aerobic digestion

'Treatment of effluent and aerobic digestion' was the title of the paper presented by **Alistair McDonald**, Managing Director of Envirobac.

The Envirobac company has recently introduced an aerobic digester, 'the Envirobac Submerged Fixed Film Bioreactor', which has a volumetric efficiency eight times greater than a normal biological system (see Fig 1).

In the Envirobac system, the waste-consuming bacteria are grown on a submerged matrix in a number of chambers through which the waste water flows. Each chamber grows a biomass most suited to the reducing strength of the waste. Air is supplied through a fine bubble plate diffuser which completely covers the bottom of the chambers. Spent biomass sloughs off the matrix and passes to the settlement chamber. The settlement chamber utilises laminar flow to maintain the same scale as the biological sections.

The system is flexible and can operate in different configurations depending on the sewage loading.

Composting

'Composting biological waste and opportunities for its use' was the title of **Ivo Svoboda**'s paper. Ivo is a member of SAC's Biochemical Sciences Department, Auchincruive, Ayr. Two reasons were given for the recent interest in waste composting. Composting could be used to produce a substitute for peat, soil conditioner or fertiliser and thus replace a slowly renewable resource and directly utilise waste as a saleable commodity. Reducing the load on land-fill sites by composting household organic wastes would be a second benefit. The UK Government's target of recycling 25% of wastes by the year 2000 lends further weight to this process.

In European countries and in the USA and Japan, the composting of domestic refuse and sewage sludge became a part of a programme for protecting the environment by minimising the land-fill disposal sites, thus reducing methane and leachate production and minimising human and plant pathogens' concentration in wastes. In some of the developing countries, composts are used for restoration of soil fertility and productivity.

— materials for composting

Composting can process a wide range of organic wastes, from highly putrescible material such as fish, animal and food processing wastes, livestock faeces, municipal solid wastes and sludges to more innocuous material such as crop residues, garden wastes, bark, wood chips, etc.

The composting material usually comprises of a mixture of high moisture, nitrogen rich wastes and dry, structure providing carbonaceous wastes. The characteristics of this feed stock determine the character of the composting process and the quality of the final product - compost. For successful and efficient composting, the feed stock C:N ratio should be between 20 to 30:1. Higher ratios will slow down the process while composting wastes with a lower ratio will result in losses of ammonia, often in large amounts.

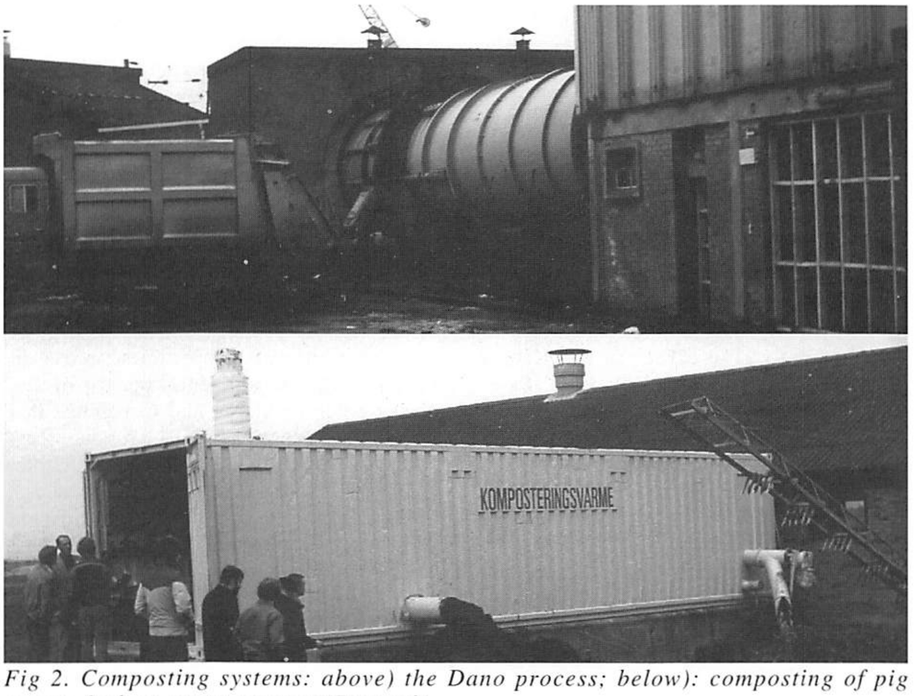


Fig 2. Composting systems: above) the Dano process; below): composting of pig manure for heat energy recovery (Denmark).

The moisture content affects the transfer of substrate and oxygen to microorganisms in the compost. Feed stock should contain 50 to 60% of water although higher values are possible if water is bound within the cells and does not affect the porosity of compost. This is influenced by the particle sizes which are recommended to be between 10 to 50 mm to allow necessary aeration of the bulk.

The homogeneity and particle size uniformity of the feed stock are usually achieved with shredders and mowers which cut the material into smaller sizes, mix and heap up the feed stock into piles.

— the composting process

The composting process is a traditional microbiological method for increasing stability and reducing odour of various wastes. The micro-organisms responsible for the degradation are mixed populations of mesophilic and thermophilic bacteria, fungi and actinomycetes. Being an aerobic process, mechanical mixing and/or forced ventilation are used to provide the required oxygen and to remove heat and moisture generated during composting. The temperature within the pile can rise during the first days of composting to 75°C or more resulting in the suppression of micro-organism activity. Therefore it is important to control temperature, by either mixing or forced aeration, at approximately 55°C for the optimal rate of biodegradation.

Composting systems range from completely enclosed (Dano, tunnel, silo) (Fig 2) to open systems (windrow composting and static piles) (Fig 3), the latter being mostly used for their simplicity and low capital and running costs. For windrow composting, the wastes are piled in long rows (approximately 3m wide at the base and 1.5m high), generally outdoors and turned periodically, turning being more frequent during the most active composting stage. This type of composting requires larger land areas and higher labour costs than static pile composting where oxygen and cooling are provided by forced ventilation at the base of the pile. Aeration at the start and at the end of composting is initiated by a timer while, during the very active stage, it is controlled by temperature feedback.

At the end of composting, indicated by compost temperature decrease to 25°C or less, the compost should be stored, preferably under cover, for at least 30 days during which time phytotoxins will be degraded. Separation into various size fractions and mixing with other additives are the last processes before bagging or bulk distribution of compost.

— compost as fertiliser, for horticulture, or as soil conditioner

Compost is valued for its high humus content which contributes both to breaking-up heavy soils and to binding light, sandy soils. It has a high water retention capacity and contains micro-organisms antagonistic to fungi and other plant pathogens.

The use of the compost is determined by the characteristics of feed stock and can be categorised mainly as a fertiliser, a potting compound or a soil conditioner.

Fertiliser compost originates from nitrogen and phosphorus rich substrates such as livestock and food processing wastes. It is used in relatively small quantities (0.1 to 0.5 l/m^2) and mostly by amateur gardeners since for the farmers, the compost's bulkiness and relatively low fertiliser value are unattractive compared to inorganic fertiliser.

The horticultural industry is the major user of all sorts of compost. Potting compost contains minimal concentration of N, P and K and is derived from lignocellulose rich substrates (straw, wood wastes, coir or even used mushroom compost). It can be combined with other material such as sand, peat, perlite or bark and enriched by N, P and K to the exact requirements of individual plant species.

Soil conditioners are usually of the lowest quality, being non-homogeneous with impurities, sometimes polluted with heavy metals originating from composted sewage sludge. Such compost is usually distributed in bulk to landscaping and land reclamation contractors.

Compost marketing usually determines the feasibility of composting though the emphasis on the recycling of organic material might override economic considerations.

Recycling

Christopher Pinnell, Assistant Divisional Manager of the Department of Water Services, Grampian Regional Council, presented a paper on 'Strategies for the recycling of sludge'. His paper outlined the environmental strategies that have been adopted by regional councils in Scotland and have had to be developed because of the considerable demands from public pressures and the needs to have sustainable outlets for the bi-product (sludge) recovered during waste water treatment.

Many settlements around the coast of Scotland have little or no sewage treatment works. In compliance with the EC Bathing Water Quality Directive, and the EC Urban Waste Water Treatment Directive, new large waste water treatment works will have to be built. In addition, after 1998, it will be illegal to dump sludge at sea (either by boat or pipeline).

At present, Regional Councils annually collect, treat and dispose of approximately 100,000 dry tonnes of sludge. About 20% is recycled to land, much as undigested (or raw) liquid or cake. Quantities to be dealt with will almost double, and the volumes available for recycling to land in Scotland will increase by fivefold.

Each regional council has its own particular problems or challenges. In Strathclyde and Lothian, much sludge is already collected, but it is disposed at sea. In Highland, Grampian and Tayside, new treatment works to serve the cities and towns on the coast will create new sludge sources. Each council has been reviewing its activities, looking at options and confirming it's own strategy. Such strategies must match local constraints and yet also ensure that the disposal or reuse of the sludges is environmentally friendly, cost efficient and sustainable. To match all these constraints has presented a challenge.

Sludge disposal focuses on the product's final destination - land, sea or air. The sea option is due to be closed off in 1998 and the air option is unavailable as stack emissions are so tight that most residuals in a chimney are now controlled by HM Inspectorate for Pollution.

Land disposal options are land-fill or agriculture and forestry applications. Recycling is the preferred option. Treated sludges can reduce fertilizer bills and improve soil condition.

Sludge as a production material

Other uses of waste water sludges include horticulture (as a peat-free substitute), application to reed beds or coppices, or, following a melt-down process as roadstone, bricks or even jewellery!!

In Grampian Region, new treatment plants will be constructed around the coastline. Benefits are substantial not just to the farmer and the forester. Cleaner estuaries and coastal waters will enhance aquatic and marine life, and help sustain a diversity of flora and fauna.

Until recently, the United Kingdom had perceived sludge in terms of a waste disposal problem. That view is rapidly changing, and in Grampian as in many other regions, full advantage of the benefits of recycling will be made.

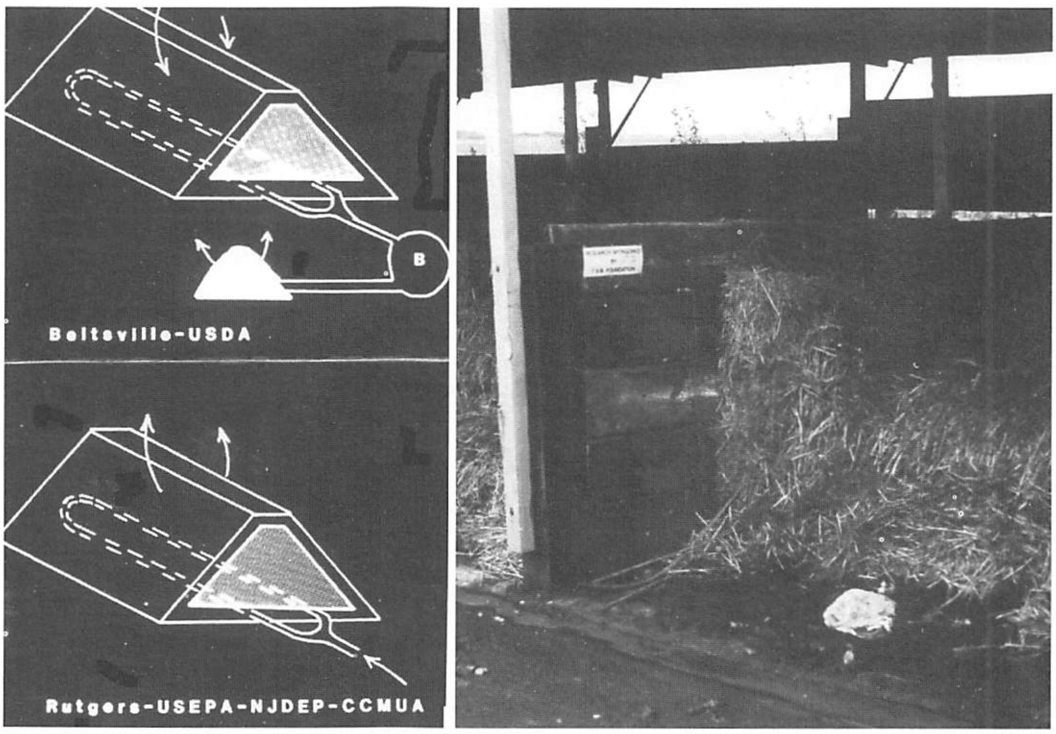


Fig 3. Static pile composting.

> The countryside is a provider of raw materials and food — but habitat protection and the interests of an urban-based society must be considered.

Integration of agriculture within an urban-based society

Elizabeth Garland, Director of the Association for the Protection of Rural Scotland, was the final speaker and widened the debate concerning the rural environment. The countryside is a provider of raw materials and food and requires a workforce for its management. Agricultural policies result in a change of landscape and the requirements both for habitat protection and for the expectations of an increasingly urban-based society were highlighted.

Integration is regarded as the key to avoiding 'specially protected reserves' in an otherwise desolate landscape.

A computer program for determining animate and inanimate power requirements for mechanised agriculture

Dr A A Aderoba

An economic model was built both to simulate and to predict the most economical mobile power system for a given farm. Three mobile power systems, human, animal and tractor, were considered. The program was tested for sensitivity to scale of farm operation, cost of labour, timeliness of operations, availability of time for work, availability of labour, value of crop, single-crop enterprise versus many-crop enterprises and availability of fuel. The program has particular applications for developing countries.

In many developing countries, it is relevant to consider human muscle power and animal power alongside tractor power for farm mechanisation. This is justifiable as the concept of mechanisation (Stout *et al*, 1970) encompasses the use of hand and animal operated tools and implements, as well as motorised equipment, to reduce human effort and to improve timeliness and quality of various farm operations, thereby increasing yields, quality of product and overall efficiency.

Critical choice of mobile power source

The mechanisation level for any farm is linked to the mobile source of power. Whilst there is a hurried desire to mechanise farms in most developing countries, the basic question for engineers and economists is whether the selection of a mobile power source with its associated equipment is the best among possible alternatives for a particular farm enterprise. This selection must necessarily depend on the profitability of the farm enterprise.

The parameters which will affect such selection include the scale of farm operations, cost of labour, timeliness of operations, availability of time for work, availability of labour, value of crops, mono-cropping versus multi-cropping and availability of fuel.

An economic model for selection of power source

This paper presents an economic model for selecting appropriate mobile power systems for farms based on the principles and parameters discussed above. The resulting computer program selects optimum size equipment and implements for each of the three mobile power sources considered and builds up the total annual cost of operation and total investment for each power system. From this model, a decision can be made as to which power system is appropriate for a given farm.

The objective of most farms is to maximize profit. This can be expressed as:

$$\text{Profit (P)} = \text{Gross Value of Production (G)} - \text{Cost of Production (C)} \quad \text{... Eqn(1)}$$

The maximisation of profit can be effected either by increasing gross value of production (G) or by decreasing cost of production (C).

Mechanisation – may improve yields, but certainly affects costs

While Giles (1966) argued that mechanisation will increase yields because of the precision in executing operations, others, for example Singh and Chancellor (1973), assert that the mere substitution of inanimate energy for animate energy in farm operations does not increase crop yields.

Both viewpoints are tenable under different conditions, but it cannot be argued that the choice of mechanisation level has a significant effect on the cost of production.

The focus of the present study is therefore on the minimisation of cost of production.

Cost of production for hand-powered systems

The annual total cost for a hand-powered system of farm production (C1), can be expressed as set out in Equation 2.

$$C_1 = SF + \sum_{j=1}^{n}\sum_{k=1}^{m}\left[\frac{N_j W_j A_{jk} H_j}{(N_j+F)Z_j} + \frac{\Phi_{jk} Y_k V_k A_{jk}^2}{X_{jk} Z_j (N_j+F) U_j} + I_j (N_j+F)\right] \quad \text{... Eqn (2)}$$

where

S	=	Cost of annual permanent labour on the farm, £/year
F	=	No. of permanent labour units on the farm
N_j	=	No. of temporary labour units required for the jth operation
W_j	=	Wage/hour for a temporary worker, £/hour
H_j	=	Hours per day available for work during the jth operation
Z_j	=	Output of labour for the jth operation, ha/man-day
Φ_{jk}	=	Timeliness loss factor for the kth crop in the jth operation
U_j	=	Fractional utilisation of total time in the jth operation
I_j	=	Fixed cost of implement required per man for the jth operation
m	=	No. of crops in the system
n	=	No. of operations
X_{jk}	=	Type of scheduling for the kth crop during the jth operation
A_{jk}	=	Area of kth crop in the jth operation, ha/year
Y_k	=	Potential yield of the kth crop, t/ha
V_k	=	Value of the kth crop, £/t

The use of a timeliness loss factor (Φ_{jk}), type of scheduling (X_{jk}) and the optimum value of temporary labour Nj in the above equation is explained in the following paragraphs.

Dr A A Aderoba is at the School of Engineering, Federal University of Technology, Akure, Nigeria.

— Timeliness Loss Factor(Φ_{jk})

Timeliness as defined by Schwart (1972) is the measure of ability to perform a job at a time that gives optimum quality and quantity of production. Timeliness costs are penalty charges which are expressed in terms of reduction in yield or sale value as a result of not performing work at the optimum period.

Timeliness loss factors are decimal reductions in the value of the crop for each day of delay in the operation and are used in building-up timeliness charges in the above equation.

Typical values of Φ_{jk} as developed by Hunt (1967) are shown in Table 1.

Table 1. Timeliness loss factors (Hunt, 1967)

Operation	*ϕ Value*
Tillage	0.0001 – 0.002
Seeding	0.002
Cultivation	0.010
Harvesting	
Corn	0.003
Cotton	0.002
Green forage	0.001
Hay (alfalfa)	0.010
Small grain	0.004
Soyabeans	0.005

Timeliness loss factors are applicable to all the three sources of mobile power.

— Type of Scheduling (X_{jk})

Three types of scheduling are recognised.

The first is 'delayed scheduling' which may be typical for scheduling perishables where the operation commences as soon as the crop is mature and then proceeds as quickly as possible before deterioration becomes excessive.

'Premature scheduling' describes the situation where the operation is planned to be completed by the optimum time while 'balanced scheduling' describes the situation where the operation time extends equally on each side of the optimum time.

The numerical values for these types of scheduling are as follows:

X_{jk} = 2 for premature or delayed scheduling

X_{jk} = 4 for balanced scheduling

—Determination of optimum number of temporary labour units (N_j)

While each farming family will have to decide how much permanent labour the farm will have to sustain, the selection of the amount of temporary labour (N_j) employed for each operation will have to be optimum to give the least cost of production.

The economic criterion is that the marginal cost of temporary labour should equal the marginal decrease in total cost of production (C_1).

This is expressed mathematically, as follows:

$$\frac{dC_1}{dN_j} = 0 \qquad \text{for all js}$$

and

$$\frac{d^2C_1}{dN_j^2} > 0$$

With the above conditions, the optimum number of temporary labour units (N_j) as determined from Eqn.(2), is given by:

$$Nj = \sqrt{\sum_{k=1}^{m}\left[\frac{\Phi_{jk}\ Y_k\ V_k\ A_{jk}^2}{I_j\ X_{jk}\ Z_{jk}\ U_j} - \frac{FW_j\ H_j\ A_{jk}}{Z_j\ I_j}\right]} - F \qquad \text{... Eqn (3)}$$

For farms where there is no established number of permanent labour units(F), the optimum value of F is contained in Eqn.(4), a first differential of Eqn.(2) with respect to F.

$$S = \sum_{j=1}^{n}\sum_{k=1}^{m}\left[\frac{N_j\ W_j\ A_{jk}\ H}{(N_j+F)^2 Z_j} + \frac{\Phi_{jk}\ Y_k\ V_k\ A_{jk}^2}{X_{jk}\ Z_j\ U_j\ (N_j+F)^2} - Ij\right] \qquad \text{... Eqn (4)}$$

It can be seen that F in Eqn (4) depends on the values of Nj and vice versa. Hence an iterative process is required to determine the values of F and N_j. A search procedure commences with F = 1, selects the optimum values of N_j and with increasing feasible values of F searches for the least value of C_1 using Eqns.(3) & (4).

Where the optimum number of temporary labour exceeds the highest possible number that can be employed from the labour market, the search (by enumeration) terminates with the amount of temporary labour that will give the lowest production cost within the feasible range of labour.

Cost of production for an animal-powered system

For an animal-powered system, a mixture of both animal and hand operations is required to allow completion of all operations.

The annual cost of operating an animal-powered agricultural system may be expressed as

$$C_2 = C_{1_b} + AC + \sum_{j=1}^{n} IA_j \qquad \text{... Eqn (5)}$$

where:

C_{1b} = The annual cost of hand operations in an animal-powered farming system. See Eqn.2 above

AC = The annual cost of animals, £/year

IA_j = The annual cost of the animal implement used in the jth operation, £/year.

Other parameters are defined as in the hand powered system.

For animal-powered operations, the most important economic and technical decisions are:-

- the selections of the optimum number of animals and
- the implement width.

The estimation of these requirements is explained below.

— Selection of the Optimum Number of Animals

The annual cost (AC) of operating animal power can be written in terms of the number of animals, the annual fixed cost, the cost of feeding and maintenance of the animals and the total timeliness costs for each of the operations, as shown in Eqn.(6):

$$AC = (FC\%P + 365Q)N_a + \sum_{j=1}^{n}\sum_{k=1}^{m}\frac{A_{jk}\,E_j}{R_j\,H_p\,N_a}\left(\frac{\Phi_{jk}\ Y_k\ V_k\ A_{jk}}{X_{jk}\ U_j\ H_j}\right) \qquad \text{... Eqn (6)}$$

where

FC% = Annual fixed cost percentage of purchase price per animal

P = Average purchase price of an animal, £

N_a = Number of animals

H_p = Typical power of an animal, kW

E_j = Energy requirement of an operation, kWh/ha

Q = Average daily cost of annual feed and veterinary bill where applicable, £/animal

R_j = A realistic maximum ratio of output to input power for the jth operation, ie. the efficiency factor

From Eqn.(6), the optimum number of animals was obtained using conventional differential calculus and is given by:

$$N_a = \sum_{j=1}^{n}\sum_{k=1}^{m} \frac{A_{jk} E_j}{H_p R_j (FC\% P + 365 Q)}$$

It is possible that the optimum number of animals calculated above may be much greater than is physically feasible. Where this is the case, an enumeration search is conducted among the feasible range of available animals and the optimum number is selected to give the lowest value of animal cost (AC).

The program does not allow for a fractional number of animals and does this by rounding up the figures to the next higher integer. Since it is possible that a loss of optimality can be obtained by this rounding up process, a second enumeration search is conducted around the immediate locality of the first answer.

The principal assumption on the animals selected is that they will be old enough to be immediately put to work.

Implement width selection

The annual cost of operation of an implement (IAj), as established by Hunt (1967), is given as in Eqn (8) above.

$$IA_j = \sum_{k=1}^{m} \left[FC_j \%P_j W_j + \frac{10 A_{jk}}{S_j W_j e_j} + \left(RM_j P_j W_j + \frac{\Phi_{jk} Y_k V_k A_{jk}}{X_{jk} U_j H_j} \right) \right] \quad \text{... Eqn (8)}$$

where

$FC_j\%$	=	Annual fixed fixed cost percentage of purchase price of implement
S_j	=	Speed of operation, km/hr
W_j	=	Effective width of implement, m
P_j	=	Purchase price per metre width of implement, £/m
RM_j	=	Repair and maintenance cost, decimal of purchase price per hour
e_j	=	Field efficiency of implement
m	=	Number of crops where k represents the kth crop
j	=	The index representing operation

Using the same differential calculus, the optimum width (Wj) is derived from Eqn.(8) and is given by:

$$\overset{*}{W}j = \sqrt{\sum_{k=1}^{m} \frac{\Phi_{jk} Y_k V_k A_{jk}}{X_{jk} U_j H_j} \left(\frac{10 A_{jk}}{S_j e_j FC_j \% P_j} \right)} \quad \text{... Eqn (9)}$$

A good estimate of animal speed (Sj) can be obtained by taking the mean value from many animal-powered farms for every animal operation.

Cost of a Tractor-Powered System

The annual cost of the tractor powered system(C_3) takes the same form as C_2 in Eqn.(5) with cost of tractor power (TC) substituting for cost of animal power (AC).

$$\left(\frac{\Phi_{jk} Y_k V_k A_{jk}}{X_{jk} U_j H_j} \right) \quad \text{... Eqn (7)}$$

$$TC = FC\% PH_p + \sum_{j=1}^{n}\sum_{k=1}^{m} \left[\frac{A_{jk} E_j}{R_j H_p} \left(\frac{\Phi_{jk} Y_k V_k A_{jk}}{X_{jk} U_j H_j} \right) \right] + FO + RMC \quad \text{... Eqn (10)}$$

where

H_p	=	Tractor power, kW
P	=	Purchase price of usable power, £
FO	=	Hourly fuel and oil cost, £/h
RMC	=	Hourly repair and and maintenance cost, £/h

The cost of tractor power (TC) can be represented as shown in Eqn.10.

The costs of repair and maintenance (RMC) and fuel and oil (FO) are considered to be a direct function of area. They are also a direct function of energy expended to cover the area. As the energy requirement is expected to be a constant for any specific farm operation, repair and maintenance and oil and fuel costs will have no influence on the optimum power level of the tractor.

The optimum power level (Hp) is found as in previous analysis by differential calculus and is given by Eqn (11) above:

$$\overset{*}{H}p = \sqrt{\sum_{j=1}^{n}\sum_{k=1}^{m} \frac{A_{jk} E_j}{FC \% P} \left(\frac{\Phi_{jk} Y_k V_k A_{jk}}{X_{jk} U_j H_j} \right)} \quad \text{... Eqn (11)}$$

As in the animal powered operations, there is a maximum limit of the available power level of a tractor. Where the optimum level of power is higher than the maximum available power, a search by enumeration is conducted among the feasible power levels to find one that gives the least cost.

The program does not help the farmer to decide whether to choose a walking tractor or a ride-on unit. This decision should be left to the farmer since others factors such as availability, local preference and ease of operation will affect the choice.

Labour in animal and tractor systems

No calculation is made for temporary labour for the animal and tractor-powered systems. It is assumed that they will be operated by the permanent labour force on the farm, on the assumption that the control of animals and tractors requires skill and managerial responsibility.

Economic Analyses

For those mechanisation plans that are both feasible and profitable, the program selects the best possible system using economic indices such as 'Net Returns', 'Net Ratio' (Annual net returns/Annual total cost), 'Capital investment' and 'Payback period'.

Computational experience

The program developed from the above model was tested with several farm systems which reflect Nigerian agricultural practices.

A typical example is a 20 ha farm with 30% of its land planted with maize, 50% with wheat and the remainder with sorghum.

The model was also tested for its sensitivity to changes in area of farm land, cost of labour, timeliness factors, availability of time for work, availability of labour, value of crop, mono-cropping system as compared to a multi-cropping system and cost of fuel.

The results of the model's sensitivity to crop area was found to be the dominant factor and is presented using the four economic parameters of:-

- Net Returns (Fig.1),
- Net Ratio (Fig.2),
- Capital Investment (Fig.3) and
- Payback period (Fig.4).

In general, from the series of test inputs, the following observations were made:

(i) There is a minimum land area (about 9ha) below which it is not feasible to operate a farm for profit motives (Fig.1).

(ii) The hand system exhibits the best net ratio at low areas (< 14ha) (Fig.2).

(iii) The animal system shows the highest net returns at medium areas (14-40ha) (Fig.1).

(iv) The animal system also exhibits the best net ratio for farms above 14ha (Fig. 2).

(v) The tractor gives the highest net returns at areas above 40ha (Fig.1).

(vi) The level of capital investment is highest in the tractor followed by the animal and hand systems respectively (Fig. 3).

(vii) In general, the tractor system requires longer pay-back periods than the other two systems (Fig. 4).

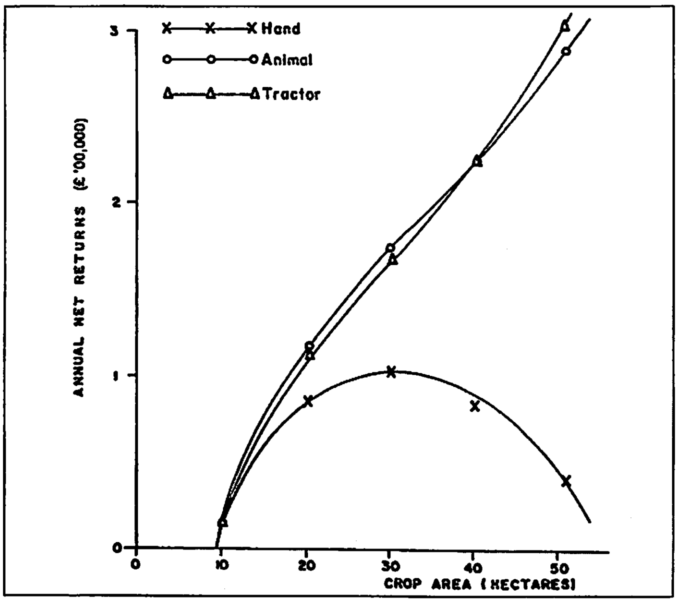


Fig 1. Annual net returns (£) Vs crop area (ha).

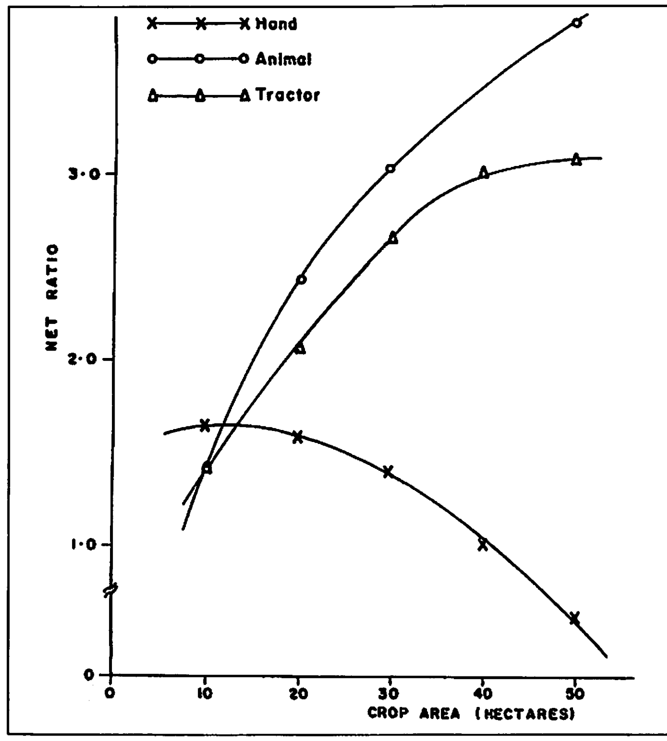


Fig 2. Net ratio Vs crop area (ha).

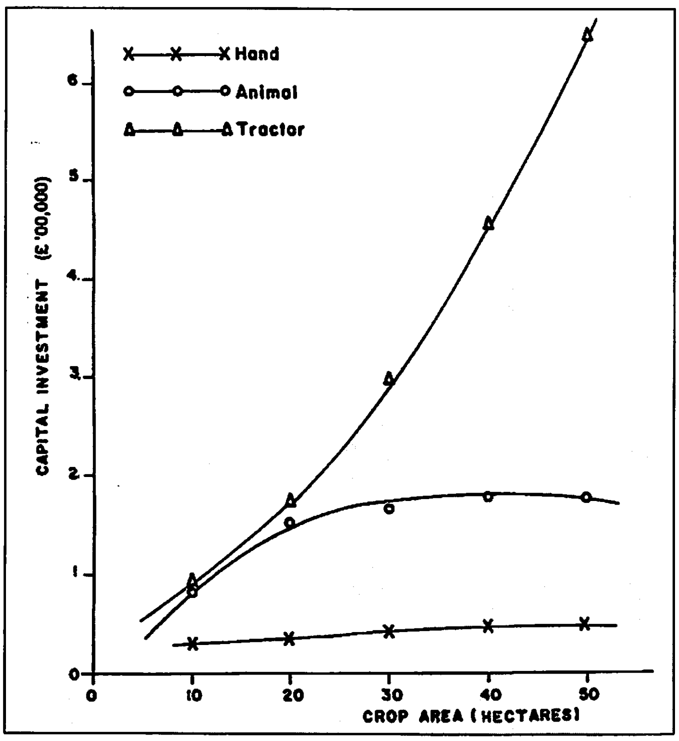


Fig 3. Capital investment (£) Vs crop area (ha).

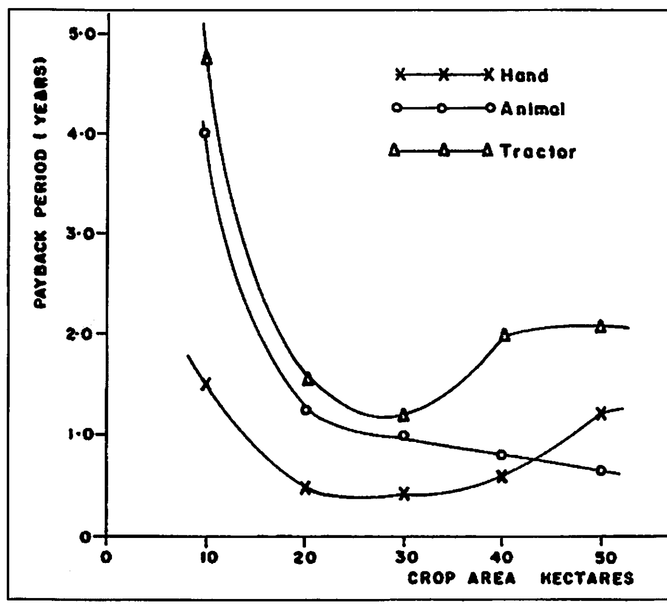


Fig 4. Payback period (years) Vs crop area (ha).

Figs 1 – 4. Sensitivity tests for crop area (0 – 50 hectares).

The above observations from the test farm may be applicable to many farms. However they are not meant to be generalisations because no two farms will have exactly the same input data and hence each farm should be analysed individually.

Discussion and conclusion

The model and its resulting computer program will enable the selection of the appropriate power base for a farm and the determination of optimum implements and labour requirements. The selection is based only on the principles of engineering economics and does not explicitly consider the socio-political effects of each mechanisation plan.

The program requires a lot of data for execution. Many farmers will not have such data at their disposal and this lack of data may be a severe setback to the use of the computer program. It is pertinent however, to emphasise that a good database is necessary for sound agricultural policy decisions. Hence farmers should be encouraged to keep records of their activities.

This model and the computer program are best used by a farm that is considering changing methods of production from a hand system to either animal or tractor-powered systems.

References

Hunt D R (1967). *Farm Power and Machinery Management.* 4th Edn.

Giles G W (1966). The first step in advancing mechanization. Getting agriculture moving: *Selected readings. Vol. II.* Agric Dev. Coun. New York.

Schwart R B (1972). Farm machinery economic decisions. *Circular 1065.* Cooperative Ext. Serv. Univ. Illinois, USA.

Singh G, Chancellor W (1973). Relations between farm mechanisation and crop yield for a farming district in India. *ASAE Paper 73-511.* St. Joseph, Michigan.

Stout B A, Kline C K, Green D A G, Donahue R L (1970). Agricultural mechanization in Equatorial Africa. *ASAE Paper 73-511.* St. Joseph, Michigan.

Research into effective treatments of pig slurry

Many projects at Silsoe Research Institute are currently being specifically directed at the problem of the pollution that results from farm wastes. Colin Burton reports on recent pilot and farm scale trials into the use of aerobic treatments to reduce the pollution potential of pig slurry.

Over recent years, waste engineering research has received a new urgency with the increasing awareness of the serious pollution consequences from farm wastes. The direction of current studies at Silsoe Research Institute reflects this with many projects now specifically directed at pollution that results from farm wastes.

Pilot and farm scale trials have been carried out by Silsoe Research Institute on the use of aerobic treatments to reduce offensive odours. However, pig slurry can also be the cause of several types of pollution to air, water or soil; there are also risks of slurry-borne pathogens. Thus work is now focused on extending slurry treatment to tackle these problems. Research facilities (Fig.1) have been developed at a pilot scale for this study.

Treatments to reduce air pollution

The main emissions from pig slurries are dependent upon the availability of oxygen. The work at Silsoe has indicated that the emissions (in decreasing order of quantity) from different treatment systems are:

- CH_4, CO_2, NH_3 and H_2S from an anaerobic environment;
- CO_2 and NH_3 from an aerobic environment, and;
- CO_2, N_2, N_2O, NO, NO_2 and NH_3 where aerobic/nitrifying conditions prevail.

The emissions of CO_2 and N_2 are not seen as pollution, being part of a balanced cycle of nutrient uptake and release.

Intensive, short (<2 days) aerobic treatments can result in large quantities of ammonia being driven off; otherwise the effect of aeration is to conserve nitrogen, either as ammonium, biomass or, if nitrifying conditions prevail, as nitrates. Such treatments minimize emissions of ammonia and the anaerobic gases but may, if denitrification occurs, result in the release of NO_x gases of which N_2O is a particularly serious atmospheric pollutant.

Controlled denitrification can lead to the production of N_2 only and is a key objective of our research.

Treatments to reduce water pollution

Water pollution incidents relating to slurry can result from oxygen starvation due to increased BOD (biochemical oxygen demand) content or eutrophication (caused by phosphates or nitrate leaching).

Our aerobic treatment trials resulted in almost 100% breakdown of the BOD content with a four day process; this represented around a third of the organic matter in the raw slurry.

Although the residual material was less reactive, it would, in time, lead to the regeneration of BOD, hence its removal may sometimes be necessary. We have used sedimentation technology to achieve this, the largely insoluble residual organic matter being removed as a concentrated sludge.

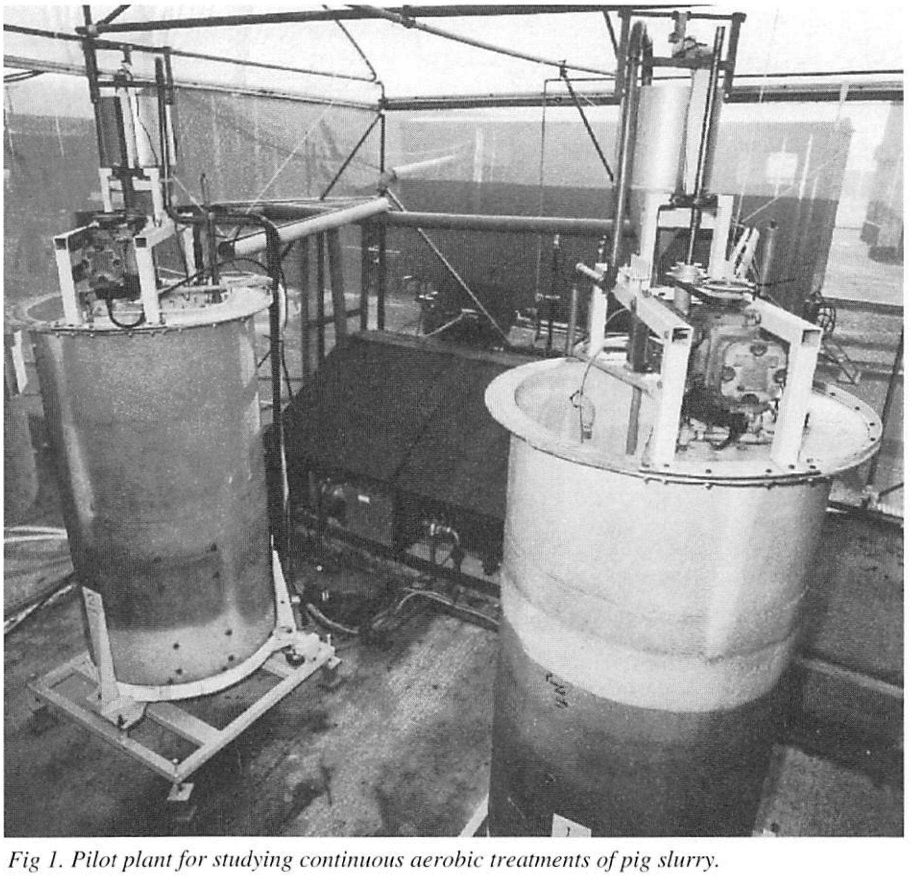


Fig 1. Pilot plant for studying continuous aerobic treatments of pig slurry.

The same process can also remove a high proportion of the phosphate, in particular if the pH is adjusted with lime. Nitrogen can be a valuable nutrient for a growing crop. However, if it is in excess, removal as N_2 may be necessary. In trials, up to 60% of the original nitrogen in the raw slurry has been removed in this way employing sequential nitrification-denitrification treatments.

Other pollution risks from pig slurry

Soil pollution from heavy metals has usually been associated with sewage sludge. However, pig slurry often contains quantities of copper and zinc. Some limited success has been achieved in removing these by sedimentation, although this does not provide a complete answer.

There are also disease risks associated with animal wastes both to the animals themselves and to the public. However, most pathogens are strict anaerobes and even short aerobic treatments will greatly reduce their numbers. High temperature (thermophilic) processes may offer a pasteurizing option if the risks are particularly high.

Acknowledgement

The above research has been funded by the Environmental Protection Division of MAFF.

C H Burton is a member of the Biochemical Research Group, Silsoe Research Institute.

DIARY

June	**29 – 30**	**Flood defence and land drainage** – Epworth, South Humberside
	Demo	*Association of Drainage Authorities, Huntingdon (Tel: 0480 411123)*
	29– 5 July	**Computer Technology in Agriculture** – Churchill College, Cambridge
	Conference	*Katherine Fort, RASE, (Tel:0203 696969; Fax: 0203 696969)*
July	**4–7**	**Royal Show** – National Agricultural Centre, Kenilworth
	Exhibition	*Melanie Allen, RASE (Tel:0203 696969; Fax: 0203 696969)*
	24–29	**Soil tillage for crop production and environment protection** – ISTRO
	Conference	Conference, Aalborg, Denmark. *Tel: 010 45 9812 6355*
Aug	**21–24**	**Engineering in Agriculture** – Lincoln University, New Zealand
	Conference	*Jennifer Swain, University of Sourthern Queensland,PO Box 282, Darling Heights, Toowoomba 4350, Australia (Fax: 010 8 61 76 355550)*
	24–26	**Soil Dynamics** – Silsoe College, Silsoe, Bedford
	Conference	*Silsoe College Silsoe MK 45 4DT (Tel: 0525 860428; Fax: 0525 861527*
	29–1 Sept	**CIGR World Congress and AgEng Conference '94,** – Milan, Italy
	Conference	*Tel: 010 39 2 430071*
Sept	**14–15**	**Potato harvesting and handling** – Doncaster, Yorkshire
	Demo	*(Tel: 0865 714455)*
October	8 - 9	**44th British National Ploughing Championships**
November	27–30	**Royal Smithfield Show** – Earls Court, London
December	13–16	**ASAE International Winter Meeting** – Atlanta, Georgia, USA

ADVERTISERS INDEX

Printed by Trafford Print (Colour) Ltd and Trafford Typesetters at Trafford House, Holly Street, Doncaster DN1 3RG. Tel: (0302) 367509 and at 112 Bermondsey Street, London SE1 3TX. Tel: 071-378 1579

BENEFITS IN EVERY FIELD

with
membership
of the
Institution of Agricultural Engineers

Professional contacts

with national and international experts in the industry from many fields who can help solve your problems.
IAgrE through its professional and technical committees provides a regular forum for members' views.

Professional qualifications

many employers recognise the value of IAgrE membership and the professional registration with Engineering Council that it provides.

Professional registration

IAgrE is a body nominated by Engineering Council to register members as Chartered Engineer (CEng), Incorporated Engineer (IEng), and Engineering Technician (EngTech). Chartered Engineers may also be registered as European Engineer (EurEng).
Registration provides a guide to engineering competence at national and international level.

Professional meetings

participation in meetings suited to the wide and varied interests of members at national conferences, regional branch meetings and within specialist groups.

Free publications

including the technical journal *'The Agricultural Engineer incorporating Soil and Water'* covering research, technical development and applications, and the *IAgrE NEWSLETTER* with news of Institution activities, members, companies and their products and job opportunities.

Other entitlements

Education and Careers advisory service; Appointments Register and advisory service;
Extensive technical library facilities.

STUDENT

MEMBER
MIAgrE

ASSOCIATE
AIAgrE

FELLOW
FIAgrE

AFFILIATE
ORGANISATION

ASSOCIATE
MEMBER
AMIAgrE

COMPANION
CIAgrE

If you have found something of interest in this journal you will surely fit one of these categories.
Send for details of membership to: The Secretary, Institution of Agricultural Engineers,
West End Road, Silsoe, Bedford MK45 4DU.