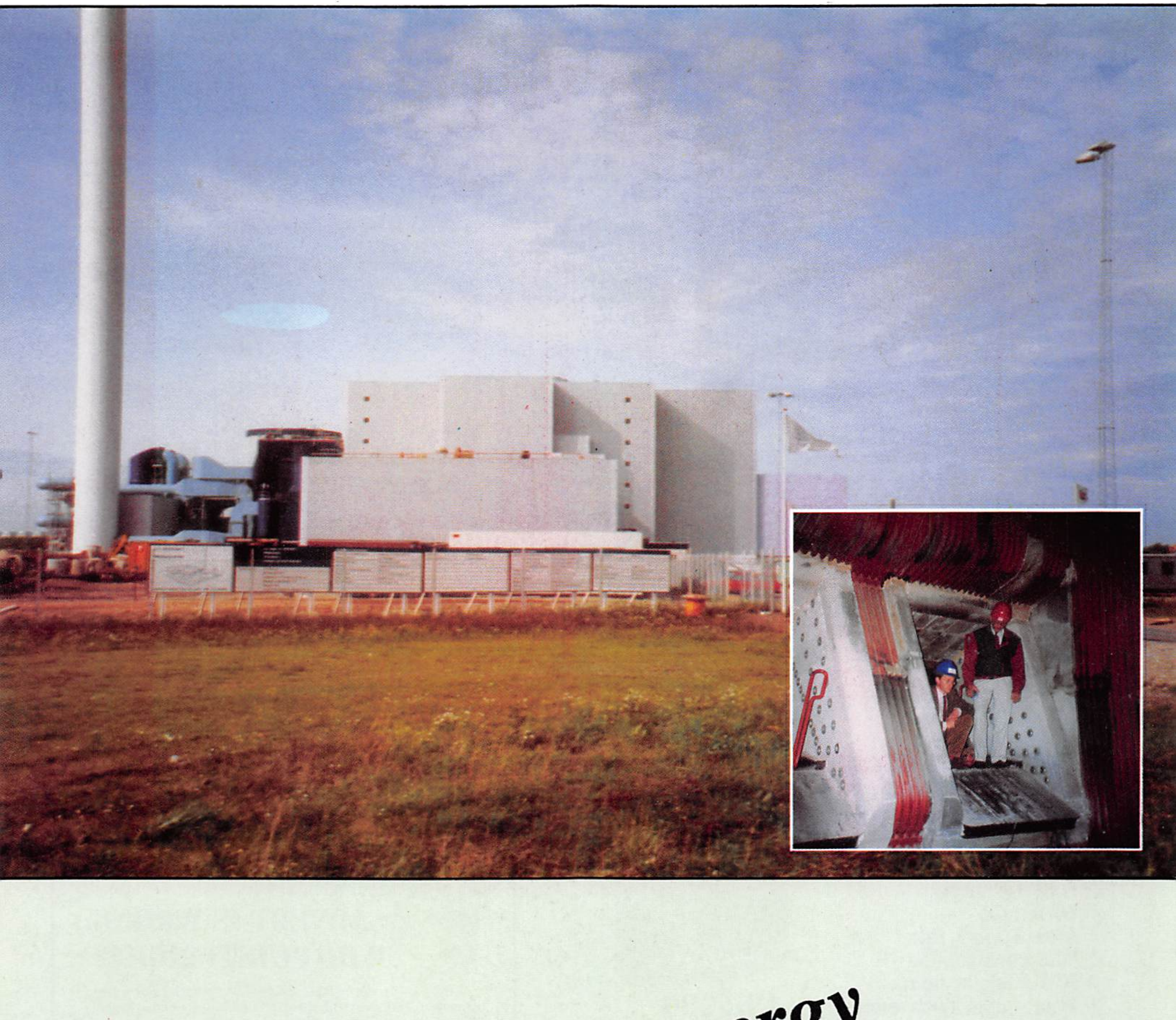
The Agricultural Engineer

Incorporating **Soil** and water

Volume 47 Number 4 Winter 1992



Alternative energy

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The Agricultural Engineer

Incorporating Soil and water

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Front cover: 23MW steam turbine/generator installation in Jutland running on wood, straw and waste. (Inset: 'cigar' burners for whole Hesston bales).

CONTENTS

COMMENT

EuroAgEng taking shape

Brian D Witney

The European Society of Agricultural Engineers was formally constituted at the AgEng92 Conference in Uppsala, following a series of meetings with representatives of National Societies. As you know, the Institution of Agricultural Engineers approved en bloc membership of EurAgEng last year but other National Societies required clarification of the role of EurAgEng and CIGR before proceeding further.

I am pleased to report that from 1 January 1993 en bloc membership of EurAgEng will comprise the National Societies of the UK, Italy,Finland, Netherlands, Sweden, Belgium, Norway, Spain and France - about 3500 members.

France constituted a federation called the Confederation Francaise D'Ingenierie Rurale et Agricole (COFIRA) from an affiliation of three societies - AFEID, AFGR and SITMA - in order to join. Switzerland has indicated its *intention* to join in 1993 subject to ratification at their National Assembly. Denmark is in the process of forming a National Society, again with the intention of joining in 1993. Germany still has to resolve internal arrangements between their two national societies before en bloc national membership can be considered.

Substantial progress has been made, but major constitutional changes take time. For this reason, the membership fees from IAgrE members for 1992 have been held over to 1993.

In 1993, high priority is being given to producing a Newsletter and to initiating a Membership Directory. A number of Special Interest Groups met at AgEng 92 to identify initial interest, and work is now in progress to publicise the proposals for their future activities. I hope that more of the IAgrE members will become involved in these Groups in due course and look to your support in ensuring the success of this new venture.

Professor Brian D Witney, Senior Vice President

Regular Features

ISSN 0308-5732

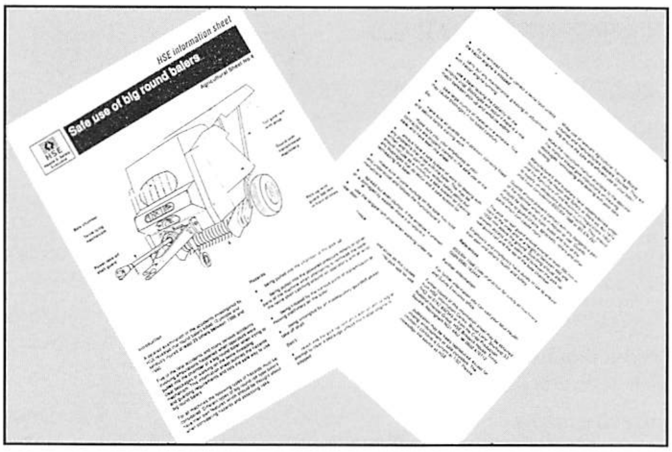
Safe use of big round balers – HSO Information Sheets

A series of information sheets is planned by the Health and Safety Executive (HSE) to encourage safe use of agricultural machinery. The first in the series 'Safe use of big round balers' is now available.

Commenting on the issue, the HSE quotes figures of ten people killed and 29 seriously injured over a five year period in accidents involving big balers. The main causes of these accidents have been in operators clearing pick up blockages, correcting twine faults and carrying out maintenance whilst the machine is still running.

Other subjects to be covered in the series include combine harvesters; all terrain vehicles (ATVs): potato harvesters and overhead power lines.

The information sheet is available from HSE Information Centre, Broad Lane, Sheffield S3 7HQ. Tel: 0742-892345.



Tube cleaner for hazardous areas

A lightweight portable cleaner for tubing and pipework can be supplied by Goodway Tools Ltd. It is air powered, making it suitable for use in areas where electric operation could prove hazardous.

Called the AWT-100 cleaner, the unit can be supplied with an extensive range of tools for use on either straight or curved pipes ranging from 1/4" up to 10" inside diameter. Pipework up to 60' in length can be accommodated, even where there is excessive scaling and hard deposits with one pass being usually sufficient for cleaning.

The machine can be fitted with continuous vacuum suction for removal of dry debris, or alternatively can be supplied with water flush where this would lead to more effective cleaning. A wide range of accessories and attachments can be supplied to cover light, medium and heavy scale deposits. Carbide drills are available for plugged pipework.

Goodway Tools Ltd, Unit 12, Alvis Way, Royal Oak Industrial Estate, Daventry, Northants NN11 5PG. Tel 0327 301414.

Suppliers to insolvent businesses – where do they stand?

– the need for standard conditions of trading

As the recession continues, the difficulties faced by businesses in the agricultural engineering industry in simply supplying goods ordered, getting paid and avoiding litigation continue to grow. It is in this context that standard conditions of trading are important.

In the opinion of city law firm Fox Williams (tel 071 628 2000) many agricultural engineering businesses either do not have standard trading conditions or have not reviewed them for some time. Still more have standard conditions, but fail to use them in a way which makes them enforceable.

Now there is a new opportunity to do something about this. For a fixed fee of £850 plus VAT Fox Williams will review an agricultural engineering business's conditions of trading, report areas of weakness and make recommendations for improvements.

For businesses which do not have existing conditions of trading Fox Williams will provide a tailored set of trading terms suited to their particular needs together with a detailed report as to how to operate the conditions of trading.

ABB Process Automation and Hewlett-Packard alliance

The recent introduction of Advant Station 500 series operator, IMS and engineering stations, incorporating open systems technologies for ABB MOD 300 and ABB Master system customers, is the result of a co-operative alliance between ABB Process Automation (a unit of Asea Brown Boveri Ltd) and Hewlett-Packard Company.

Incorporating workstation technology from HP brings a UNIX operating system with X Windows to ABB Master and ABB MOD 300 automation systems. This results in a direct connection to control and plant networks.

ABB Process Automation is one of the world's largest automation suppliers, with annual sales of more than $1 billion (US). Hewlett-Packard Company, international manufacturer of measurement and computation products and systems, is active in approximately 100 countries and had revenue of $14.5 billion in its 1991 fiscal year.

Advant, MOD 300 and ABB Master are trademarks of Asea Brown Boveri. UNIX is a registered trademark of UNIX System Laboratories, Inc. X Window System is a trademark of the Massachusetts Institute of Technology.

Arable wood crops for electricity – how profitable?

A report prepared by Silsoe Research Institute examines whether it is profitable for the arable farmer to grow a wood crop to produce electricity for the National Grid. The study considers the factors involved in crop production and on-farm electricity generation and compares the profitability of electricity generation throughout the year with conventional arable cropping.

The study is based on a 22-year plan for a 250ha farm with 20% (50ha) coppice and electricity generation from year 5, with a 3-year harvesting cycle during the winter months. This requires one 100kW generating system running for 19h/day. It is assumed that electricity is sold for 6p/kWh all year round under a non-fossil fuel option contract.

The Silsoe Arable Farm Model is used to calculate the best farm system with and without coppice. It examines the consequences for labour, machinery and cropping of introducing arable wood and determines the optimum system with and without the coppice crop. The profit (or loss) each year can then be calculated.

The report (£5 including p&p) is available from Silsoe Research Institute, Wrest Park, Bedford, MK45 4HS. Tel: 0525 860000.

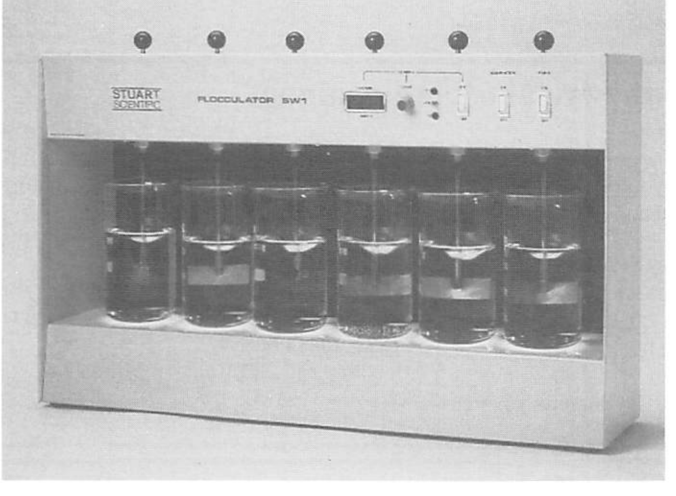
Loading to maximum, within legal limits

P M Electronics, the Bradford based specialist in On-Vehicle Weighing Systems has developed a unique 5th Wheel Weighing System to overcome the problem of vehicle overload.

Historically, operators of articulated vehicle fleets, particularly those involved in multi-drop distribution, have failed to overcome the problem of accurately loading the vehicle to its maximum permitted weight whilst at the same time guaranteeing legal operation. This is especially so on multi-drop delivery or when part distributing goods.

The PME 5th Wheel Weighing System is simple and economic to fit. It operates by precisely monitoring the imposed loads through the Tractor 5th Wheel and then displaying the information to the driver. With the Incab Display automatically identifying any multiple of trailer/tractor combinations, total flexibility is provided.

P M Electronics Ltd, 413 Cutler Heights Lane, Bradford BD4 9JL (Tel: 0274 660792).



The new SW1 Flocculator from Stuart Scientific Limited (Tel 0737 766431) is designed to undertake flocculation analysis of up to six samples simultaneously, all of which will receive absolutely identical stirring regimes. As floccules develop, these can be clearly observed against the instrument's matt black background; and, as a further aid to monitoring, sample beakers are diffusely illuminated from underneath too.

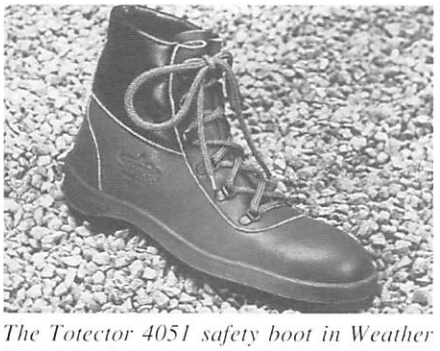
Drill for sticky soils and trash

A seeder unit with a unique non-stick crumbler roller is claimed to overcome the problems of operating in clay soils and trashy conditions. Used in conjunction with a power harrow, the Guttler drill is being imported from Germany by Northumberland machinery dealer and contractor, David Wox (Farm Sales) based at 69 Station Road, Stannington, Morpeth (0670 789581).

The key to the machine's success in drilling in all conditions is the packer unit, which consists of a series of patented cast steel rings with prism serrations. This profile breaks up clods and firms the seedbed to conserve moisture, without a build up of soil or trash.

The seeder units will fit any make of rotary harrow with working widths of 3, 3.5 and 4 metres – units up to 6 metres are available in Germany. Additionally, growers can buy the special non-stick press units to replace crumbler bars behind harrows or as a separate press unit. The 3 metre seeder unit is expected to retail at about £4,700.

Foot related accidents



The Totector 4051 safety boot in Weather Tough leather.

Manufacturers of safety footwear, Totectors Limited calculate that nearly one million working days were lost in this country in the financial year 1989/90, as a direct result of reportable injuries to feet and toes.

The most common kind of accident causing a major injury to feet or toes was being struck by a moving or falling object. Slips, trips and falls on the same ground level also accounted for a high percentage of accidents, as did being struck by a vehicle or foot injuries caused when handling equipment or product.

Totectors offer a range of safety footwear suitable for the agricultural environment with a toe cap resistance of up to 200 Joules, meeting all international standards.

To combat the problems of slips and trips Totectors test many varieties of sole patterns and materials both in their own testing laboratory and out in the field. Continual feedback from customers on comfort, durability and performance is assessed to increase the overall performance level of shoes or boots used in the outdoor environment.

Full details of Totectors range of safety footwear and protective clothing can be found in their free colour catalogue.

Totectors Limited, Totector House, Rushden, Northants (Tel: 0833 410888).

Revolutionary heat source for welding

CONNECT – the monthly magazine on materials joining technology from the Welding Institute (TWI) – has lately carried an article on the development of a novel machine which uses microwave energy to generate a controllable plasma discharge.

This development, jointly carried out by TWI and the University of Liverpool, offers a new heat source which, it is said, will make possible high quality, high speed welding; cutting and surface treatment at a fraction of the cost of current laser and electron beam techniques.

TWI Information Services, Abington Hall, Abington, Cambridge CB1 6AL. (Tel: 0223 891162).

Groundwater salinity
– Australian computer program predicts effects of tree planting

Australian soil scientists have developed a computer program to predict the salinity-reduction effects of tree-planting on land whose groundwater could be contaminated by salt. Designed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the TOPOG-IRM program enables land managers to experiment with a range of options without physically having to do the work.

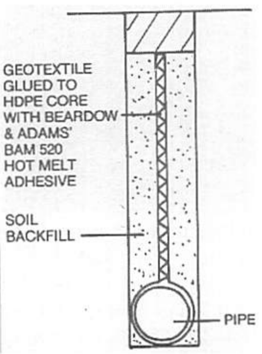
Dr Joe Walker of the CSIRO Division of Soils said the program was unique because it showed how water moved through a catchment zone and how plants affected that movement. The TOPOG-IRM is one of several programs developed by the CSIRO to predict the impact of a wide range of land uses and natural events, such as flooding, soil erosion and water quality.

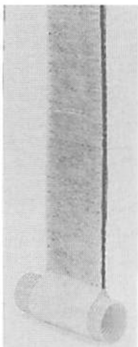
Joe Walker commented: "For salinity control, we know that planting trees and deep-rooting crops can be an effective way of soaking up water from the soil and stopping saline groundwater rising to the surface. However, we no longer have time to plant trees in what we hope are the right places, only to find in 10 years' time they have had no effect. This is where TOPOG-IRM is useful. It can tell us where trees and crops are likely to succeed in controlling salinity, and where they won't make any difference. This means we can spend tree-planting money in the wisest way."

TOPOG-IRM uses information on plants, soil, climate and topography to assess ways of soaking up excess groundwater and preventing water-logging, a key factor in causing salinity. The CSIRO believes this computer program is the first of its kind to link information on plant growth with water movement through landscapes.

The program projects a three-dimensional landscape on to the computer screen, complete with areas of vegetation, hills, and valleys. Rainfall is keyed in, creating an effect like ink seeping into a sponge. With water-logging showing up as a dark blue area the aim is to minimise this by suitable control.

We are indebted to Trevor Rees of Carrum, Victoria, Australia for sending the above item.





New hot melt adhesive aids land drainage

The Stardrain fin type drainage system from Earth Products Ltd is a combination of geotextile and HDPE bonded with BAM 520, the new Beardow and Adams hot melt adhesive.

The fin, of high density polyethylene (HDPE) with the surround of geotextile filter fabric, provides a large surface area through which water – but not silt – can permeate and flow down to the PVC pipe sleeved to the bottom of the fin. The BAM 520 adhesive is not affected by cold wet soil conditions and the drainage system requires nothing more than soil backfill for successful functioning.

Stardrain is typically supplied in depths specific to customer requirements.

Earth Products Ltd are at Fearnought Works, Huddersfield Road, Holmfirth HD7 2TT. Tel: 0484 688582.

Beardow and Adams are at Milton Keynes (Tel: 0908 315474).

Predicting vehicle stability using portable measuring equipment

Gwilym Owen, Alastair Hunter, Chris Glasbey

Vehicles are used off-road on difficult terrain in a wide range of industries. In general, the driver has inadequate information on the safe operating slope for his vehicle and overturning accidents occur regularly.*

A method of predicting the stability of a wide range of vehicles using weighpads has been developed at the Scottish Centre of Agricultural Engineering. The authors here describe the techniques involved and explain the measurement procedure. A new British Standard has been prepared.

The static stability limit of tractors, trailers, tankers and forestry forwarders can be measured on a tilt table. However, installing a tilt table is expensive and few are available. Weighpads are commonly available, portable and are safe and simple to use. A new and inexpensive measuring technique has been developed at the Scottish Centre of Agricultural Engineering using portable weighpads.

Basis of the technique

The basis of the technique has been previously elaborated (Spencer *et al* 1985) and is reiterated briefly here, Fig 1.

Using a weighpad to measure the wheel to ground load, R_n, at different slopes, β, a curve can be fitted through the data points to predict the angle, β_s, at which the normal load becomes zero. In practice two measurements of wheel load only are required, high load, R_H, and low load, R_L,

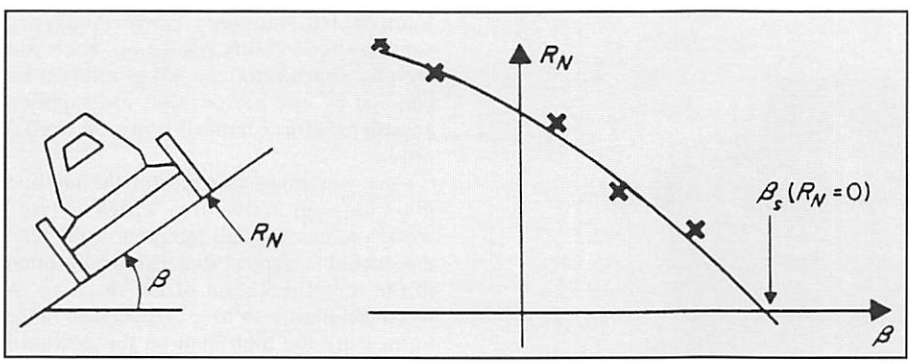


Fig 1. Basis of stability prediction technique.

and the corresponding slope of the vehicle at these loads, Fig 2. These measurements can easily be achieved when using a natural or prepared slope by placing the wheel load to be measured first 'uphill' and then 'downhill' giving a 20° change on a 10° slope; the load measurements can be repeated and averaged.

Stability prediction is carried out using a sinusoidal model fitted through the high and low load measurements. Given expected loads X_1 and X_2 at slopes Z_1 and Z_2, the predicted stability is:

$$\beta_s = \tan^{-1}(K/L)$$

where $K = X_1 \sin Z_2 - X_2 \sin Z_1$

$$L = X_1 \cos Z_2 - X_2 \cos Z_1$$

Confidence limits are given by Fieller's theorem (Kotz and Johnson 1983) as:

$$\tan^{-1}\left[\frac{Q \pm \sqrt{(Q^2 - PR)}}{R}\right]$$

where

$P = K^2 - \frac{1}{2}EN^2(2 - \cos 2Z_1 - \cos 2Z_2)$

$Q = KL - \frac{1}{2}EN^2(\sin 2Z_1 + \sin 2Z_2)$

$R = L^2 - \frac{1}{2}EN^2(2 + \cos 2Z_1 + \cos 2Z_2)$

E is the mean square error in load reading

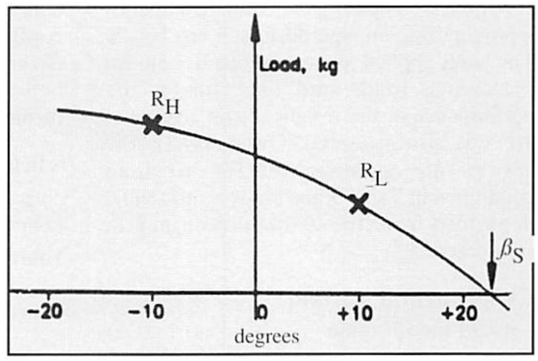


Fig 2. High and low load measurements.

and N is the normal statistic at the appropriate probability level.

The experimental work

– machines and equipment

Eleven machines were used in the work, Table 1. These were representative of the wide range used in agriculture and also extended into the construction industry, forestry and amenity ground maintenance. The weight of the machines ranged from less than 1t, for the compact tractor without attachments, to over 12t for the articulated steer loader with a full bucket. Tyre sizes ranged from 10.0/80-12 on the bale transporter to 20.5-R25 on the Case shovel. Tyre pressures also varied from 12psi on the MF 185 tractor to 54psi on the Case machine and 60psi on the Collins silage trailer.

– weighpads

Six models of weighpad were used in the

*See Owen and Hunter, 1983.



A G M Hunter (centre) and G M Owen (at left) are responsible for Vehicle Safety Research at the Scottish Centre of Agricultural Engineering. C Glasbey (at right) is Head of Research and Training in The Scottish Agricultural Statistics Service.

Table 1. Machine code names and type.

Code	*Description*	*Construction*
MF185	Two-wheel drive tractor	Wheel steering
BTRANS	Bale transporter	Trailed
MF680	Four-wheel drive tractor	Wheel steering
COLLINS	Silage trailer, tandem axle	Trailed
RECO	Muck spreader	Trailed
ISEKI	Compact tractor with attachments	Wheel steering
MANNS	Round baler, chamber	Trailed
CASE	Bucket loader	Articulated
JCB	Digger/bucket loader	Wheel steering
HOLDER	Small tractor	Articulated
BRUUNETT	Forest forwarder	Articulated

experimental program, Table 2. Two of these models were available in house at SCAE, the others commercially available.

All the weighpads were calibrated against a proving ring on a purpose built test bench. The loads applied to the weighpads included off-centre loads and side loads; the performance of the weighpads on a slope of 10° was also measured (Owen, 1988). The results are summarised for all load conditions in Table 3 and show a substantial departure from the claimed accuracy in some cases.

Experimental method

– use of the tilt table

The tilt table was used as an adjustable slope on which to evaluate the weighpad method, Fig 3. The tilt table was also used for making direct measurements of stability by elevating a machine to its tip limit. Weighpad measurements were taken on table angles which were nominally 1/6, 1/3 and 1/2 the tip limit of each machine. The machine angle and axle angle readings were taken at a predetermined reference position on each vehicle with known zero reading on level ground.

All the tilt tests were carried out on the contour line of the slope. Earlier tests had confirmed that the effect of heading angle deviations, within ± 5° from the contour line had little effect on the accuracy of the method (Owen, *et al*, 1988).

– field tests

Two field tests were selected, one with an 8° nominal slope, and the other a 16° nominal slope. At each site, the slope was uniform over a sufficient area to accommodate the machine and allow it to be driven straight along the contour line when approaching the weighpad. It was found that the contour line of the test slope could be determined within 5° by eye using a taut line which was then left to guide the driver.

Using two weighpads, one under the uphill wheel and the other under the downhill wheel, allowed for closer correspondence between the vehicle angle and ground angle than using one weighpad which tended to tip the vehicle slightly. Allowance had to be made for side slip of the vehicle on the side slope when driving onto the weighpad; the position of the weighpad could also be adjusted immediately prior to driving on. After taking the first weight which could be either the high or low load, the vehicle was driven off the weighpad, turned around and driven on again to obtain the complementary load reading for the same wheel.

Table 2. Code names and details of weighpads.

Codename	*Model*	*Commercially available*	*Max load tonnes*	*Accuracy kg*	*Display type*
MK1	SIAE MK1	No	5	±3	Digital
MK2	SIAE MK2	No	5	±1	Digital
PAD	SAW 10	Yes	10	±25	Digital
TD	MIN.10.T	Yes	10	±20	Digital
CKWT	Checkwt MK4	Yes	9	±5/t	Dial
HAWKLEY	Highwayman	Yes	6.5	±20/t	Liquid column

Fig 3. A bale transporter stability test using weighpads on the tilt table.

Specification of weighpads

– Commercially available weighpads

Four commercially available sets of weighpads were evaluated, and of these only the Trevor Deakin (TD) and the PAT10 models proved suitable for vehicle weighing on slopes. Their quoted accuracies are ±20kg and ±25kg respectively, with the PAT10 weighpad running out to ±50kg at a load of 10t, but they performed very similarly for stability prediction. Each pad weighs approximately 35kg and can be handled by one person; they are supplied complete with a battery-powered digital display.

Any weighpad suitable for the method must have an active area which is large enough to take the full footprint of the tyre, the critical weighpad dimensions are often in the travel direction of the machine. A weighpad must also have an adequate range to measure the high load on the downhill wheel when the vehicle is on the test slope; this can be up to 50% more than on level ground.

The requirements for a weighpad may be summarised as follows:

- Portable
- Battery-powered
- Remote digital readout
- Zero can be reset (auto preferred)
- Resolution 10kg or less
- Accurate to ±25kg or better
- Range up 10 t
- Minimum active surface 400 mm long by 500 mm wide
- Insensitive to side loads
- Performance unaffected by slope

– Benefits from high accuracy weighpads

The MK1 and MK2 weighpads of an in-house design had been included in earlier tests: their quoted accuracies were ±3kg and ±1kg respectively over a range up to 5t. The predicted stability results for all vehicles on these weighpads showed significantly less variability than on the less accurate commercial weighpads.

The benefit of high accuracy weighpads was most important for testing the small Iseki compact tractor without attachments; the wheel track of this vehicle was less than 1m and the load on a single rear wheel was 0.26t. When the tractor was elevated to the test slope, the load change under the uphill wheel was only 100kg, compared with 1000kg for the Case shovel.

Accuracy of prediction

– machine angle versus table angle

Positive bias values had been repeatedly observed in the results, Fig 4, and it was suspected that these were due to machine tilt. Tyre and/or suspension deflection allowed the machine to tilt to an angle greater than the table angle. This effect was studied in detail (Hunter, *et al*, 1990).

It was found that the theoretical model of the relationship between wheel load and machine angle was very close to sinusoidal and the empirical results for machine angle fitted the sinusoid better than the results for the table angle. It was therefore concluded that the weighpad method was better at predicting machine angle than table angle, and the difference between the two angles could account for the bias in the results. Correcting the bias for the results in Fig 5 shows a major shift towards zero and again the majority of predictions are within the 10% boundary.

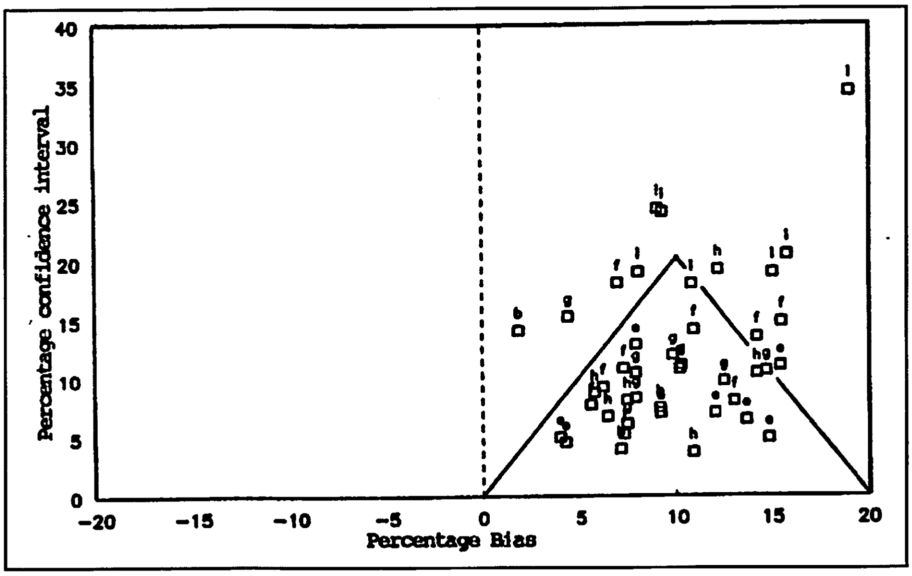


Fig 4. Plot of predicted bias and confidence interval widths based on paired results from the field using two commercial weighpads.

Table 3. Summary of weighpad evaluation.

Codename	*Bias %*	*S.d. kg*	*Max load,t*	*Exception*
MK1	−1.5	11	5.1	edge load; max 3.0t
MK2	0.5	13	5.1	edge load; max 3.0t
PAT	−2.1	32	10.1	edge load; max 3.8t
TD	2.2	41	8.7	side load; −1.1% bias, sd 63 kg
CKWT	2.3	32	7.7	edge load; 0.6% bias, max 3.8t
HAWKLEY	very sensitive to side load, and orientation on slopes.			

– variability of prediction

Assuming that the weighpads are within the specification given above and assuming that the test slope is half the expected tip limit, the variability should fall within the ranges shown in Fig 6. Excluding the compact tractor and the articulated steer tractor – both light machines with high stability limits – the confidence interval should be less than 10% (±5%) and less than 4° (±2°).

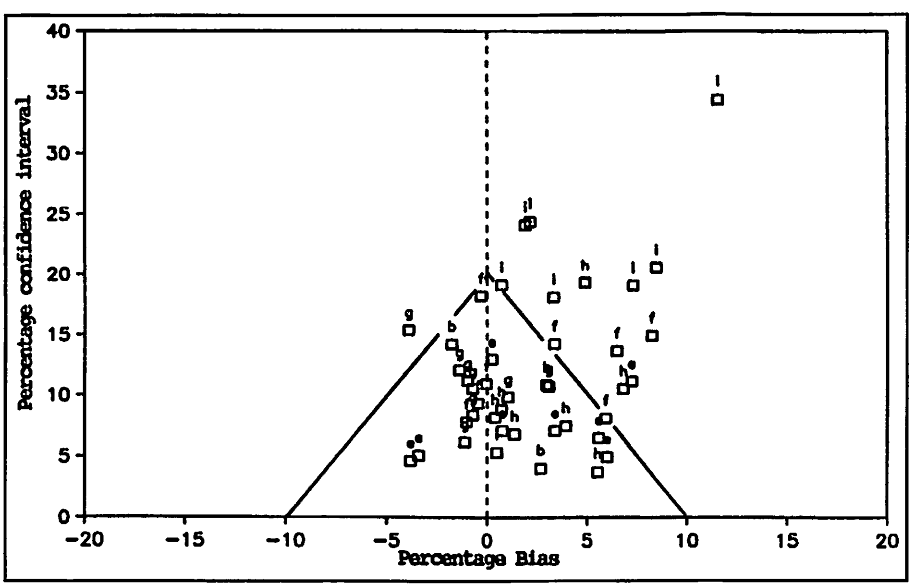


Fig 5. Plot of predicted accuracy with paired field readings using corrected bias values after allowance for the tilt.

– calculation method

At the end of the measurement procedure, the following will be available with which to calculate the stability of the machine:-

Wheel load (high)	R_1	t or kg
Machine angle	β_1	degrees
Wheel load (low)	R_2	t or kg
Machine angle	β_2	degrees

The stability prediction follows the simple formula:

$$\beta_s = \tan^{-1}\left[\frac{R_1 \sin\beta_2 - R_2 \sin\beta_1}{R_1 \cos\beta_2 - R_2 \cos\beta_1}\right]$$

The formula is most easily computed with a hand held programmable calculator which also prompts the user for the data values in the correct order.

Measurement procedure

The test slope must meet the needs of accurate prediction and safe procedure; a steeper test slope leads to greater accuracy and a gentler slope reduces the danger of the machine overturning during a test. A slope of half the tip limit of the machine will normally meet these needs.

If the approximate tip limit is known from previous experience or calculation and the user requires an accurate prediction using the weighpad method, then a test slope equal to half the approximate tip limit should be used. However, if the approximate tip limit is not known, then the weighpad method should first be used on a gentle and safe slope, of say 5°, to obtain the first estimate of the tip limit and hence determine the required test slope.

A suitable site must have a uniform gradient and a sufficient area to accommodate the test machine as well as the towing vehicle if, for example, a trailer is under test. The gradient of the site should be measured using the inclinometer set on a straight length of wood, about 2m long, to average out ground roughness.

If extensive measurements are to be carried out then a prepared site would have advantages. The contour line could be pre-marked and the surface treated to reduce rutting.

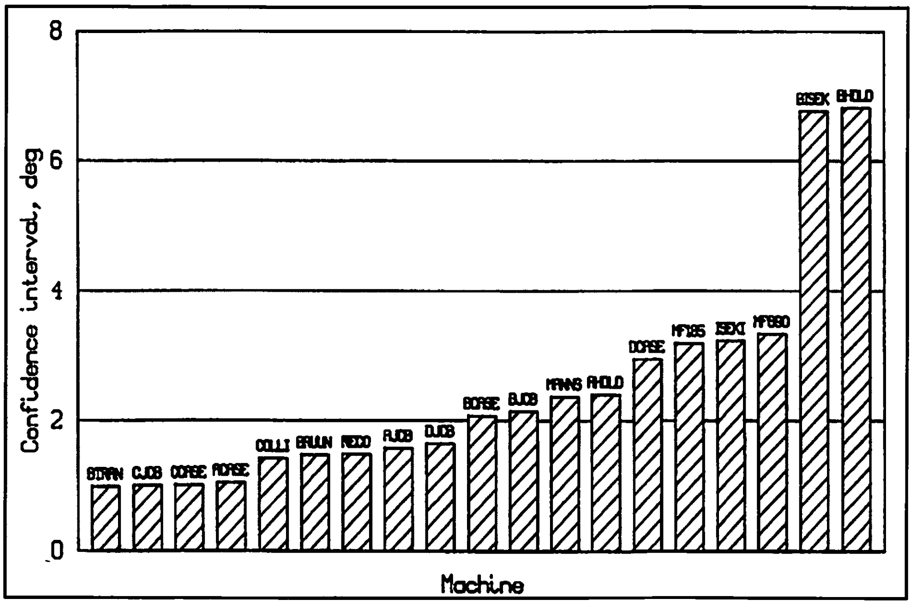


Fig 6. Confidence interval for all machines, calculated from the empirical model given in degrees.

Range of vehicle types

The method has been evaluated for a representative range of machines. From the results todate a list has been drawn up of vehicles which have been shown, or are expected, to be suitable for stability prediction by this method and also of those vehicles which for one reason or another must be regarded as outside the scope of the method for the present. Details are given in the adjacent panel.

Conclusions

The weighpad method permits stability to be measured where otherwise it would not be and is a significant contribution to safety. The weighpad method predicts the machine tip angle at the point of tip, which can be regarded as a better indicator of stability than the table angle because it is the angle that can be measured by an inclinometer mounted in the driver's cab. The method has been fully assessed with a range of different weighpads and machines, identifying both its advantages and limitations. The system is safe, accurate, portable and simple to use.

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Spencer H R, Owen G M, Glasbey C A (1985). On-site measurement of stability of agricultural machines. *J. agric Engng Res*, **31** (1): 81-91.

Suitable vehicles

Machines shown by results of trials to be suitable for stability prediction:

- single axle and tandem axle trailed equipment, eg trailers, bale transporters, muck spreaders;
- four wheel self-propelled machines, either two or four-wheel drive and wheel steered, eg tractor fork lifts, loaders and diggers;
- four-wheel drive vehicles which are steered by articulation of the chassis or frame, but only when the chassis is straight.

Machines not yet specifically tested but expected to perform satisfactorily, with the provisos given:

- dual wheel trailed equipment if the wheel spacing is suitable for driving onto the weighpad(s);
- trailed equipment with liquid loads, whether full or empty, eg sprayers and slurry tankers;
- tractors with mounted sprayers if the liquid is given time to settle;
- combine harvesters if the weighpad is large enough for the wheels;
- four-wheel tractors with suspended cabs or suspended axles;
- four-bogey self-propelled equipment, eg forestry forwarders if all bogey wheels can be fitted on a weighpad set.

Unsuitable vehicles

Vehicles not yet evaluated using the weighpad method, or which can not be predicted with sufficient accuracy, and must be regarded as outside the scope of the method for the present:

- articulated steer mahcines, when in the steered position because the machine geometry is completely changed from the straight position resulting in complex stability changes;
- multi-axle machines except those with a 'wheel or bogey at each corner' because loss of stability is indeterminate;
- tracked vehicles;
- lightweight machines with axle weight less than 1t and heavy machines with axle weight greater than 10t.

Farm machinery: 12th edition
by Claude Culpin

Blackwell Scientific Publications, London
Price: £24.99 (paperback)

It is really difficult to say something new about this work. Suffice to say when asked: "I can take one book on the subject so which one?" the answer regarding farm machinery and mechanisation is simple, "take Culpin". It remains the leading work on the subject and is recommended to all who work in mechanised agriculture, including students, farmers and advisers. It is also a useful reference for those working in the agricultural industry as designers, developers, producers and technical sales.

This new edition is a most extensive revision and incorporates most of the developments of recent years. There are many updated illustrations with new material particularly on automatic controls of tractor and equipment. As always the quality of presentation is first class.

So full marks for the new edition which sits on the shelf as the most complete work of its type.

MJH

Tools for Agriculture: A guide to appropriate equipment for smallholder farmers

Intermediate Technology Publications
ISBN 1 85339 100X Price: £30

The fourth edition of this guide was launched by the Intermediate Technology Development Group (ITDG) at this years' Royal Show. This unique guide, first published in 1967, continues to provide a most valuable source of information on appropriate tools for small scale farming. It is now produced from a computer database compiled jointly with the Groupe de Recherche et d'Echanges Technologiques .

Data is selected from more than 1200 manufacturers in over 90 countries. The work starts with a useful outline of how to use the guide. This is followed by a very useful introduction by Ian Carruthers and Marc Rodriguez on the strength and constraints of small holders farming and the maintenance problems of agricultural equipment. This serves particularly well in putting the whole subject into perspective.

The bulk of the work is then subdivided into logical sections including field power and soil preparation through to bee keeping. Each section has an introduction by an authority on the particular subject. This actually transforms the book from purely a guide into a more informative educational document. In my view the book can clearly be considered a valuable text for students of mechanisation and development.

Each section is fully illustrated with line drawings and photographs. Also included are sources of further information and a manufacturers and equipment index.

This is a unique guide and course of information on small scale farm equipment. The new edition should be readily available to development workers, manufacturers and smallholders as well as being present on the library shelves of educational establishments involved in agricultural development.

MJH

John Deere Tractors and Equipment
Volume 2: 1960–1990
by Don Macmillan and Roy Harrington

American Society of Agricultural Engineers
ISBN 0-929355-19-9

This is Volume Two of a comprehensive record. Volume One was given a 'rave' review by myself in an earlier *Agricultural Engineer*. This instalment begins where Volume One left off, at the end of the two-cylinder engine era.

The text is divided into two main parts. Part I looks in detail at the company history over this 30 year period, starting with the decision to abandon the 2-cylinder tractor design and introduce the new multi-cylinder tractors; from there, the development of a full new line of attachments and equipment to utilise the new tractors design features and then the increase in size capacity and technology of harvest equipment. This first part of the work describes how the company developed, branched out into industrial equipment, consumer products and overseas ventures during the 1960's, '70's and '80's.

The second part of the book is essentially a product review, with a host of excellent photographs covering the development of each type of machine produced.

Together these two sections provides the reader with a broad overview of how the John Deere company progressed through three decades.

The final short section is an appendix which provides the reader with data and specifications of the company and its products. There is no index to the work which is somewhat of a drawback.

This small gripe apart, it is – as was the first volume – a beautifully presented work. For those with an historic interest in farm machinery I am sure it is a must. For the rest we would be happy to think it is available to flip through when we feel the urge for nostalgia. So I need to encourage libraries to make sure and stock it.

MJH

Surveying: 6th Edition
by Bannister, Raymond and Barker

Longman Scientific & Technical
ISBN 0-470-21845-2 Price: £16.99

This classic text on surveying will be familiar to all those related to the discipline. It goes without saying that it comes with the highest recommendation from this reviewer.

The real interest is whether this new edition, revised by the original authors with the help of R. Barker, maintains the high standard at the same time updating the text. I am pleased to be able to report that it does just that. A major effort has been made to readjust the format of the book to take into account the major change from optical to electromagnetic distance measurement. Much greater emphasis has been placed on total station instruments, data loggers and the global positioning system.

One section I felt has been much improved is that dealing with 'setting out'. It is now a simple and concise text made even easier to follow with good illustrated examples.

The book has always been a very full, precisely presented treatment of the work. This makes it almost the perfect reference for those undertaking courses related to any form of construction, building or soil and water engineering from BTEC through to Higher Degrees. It is also an excellent field reference for those whose work carries them into the realms of surveying.

As before, the book is littered with worked examples and diagrams and there are still very good exercises included at the end of the chapters.

As indicated earlier, the logical and accessible style has been continued in this new edition producing a readable, indepth coverage of the subject. A must to anyone who is learning or practising in this field.

MJH

Farm welding
by Andrew Pearce

Farming Press Books, Ipswich
ISBN 0852362307 £12.95 (hardback)

This book is an excellent first primer and improver. The author attempts the difficult task of leading people to develop a skill from pictures and external captions. The result is a most successful work providing the reader with all that is required to produce welding to a repair level. Subjects covered are arc welding, MIG/MAG welding, gas welding and cutting and even soldering. There is also a section on basic blacksmithing skills so essential in farm machinery repair.

This book is, of course, aimed at on farm needs and covers very much the requirements of beginners and improvers. It is very well structured, easy to follow with many excellent illustrations.

At £12.95 it is good value as a practical guide for those seeking to extend their general repair skills.

MJH

Gasification – providing markets for biomass crops

Richard Landen reports on the latest Belgian work and suggests that the new trials now set up in Northern Ireland could produce the firm evidence needed to encourage UK farmers to take up alternative 'energy' crops.

The technology of gasification of solid fuels is not new. Indeed, the destructive distill-ation of coal was widely practised in the UK until the advent of natural gas from the North Sea. On the other side of that same sea, recent developments in the gasification of wood have attracted considerable interest: but why?

Much public money has been spent, and much work performed, on the subject of biomass fuels as alternative farm crops. However, the uptake of these ideas has been slow – there is no market for the primary products. As a way out of this situation, it has been mooted that on-farm conversion to more saleable products could help develop these crops, as well as providing value-added opportunities for the farmer.

Electricity is in many ways the highest grade of energy. It is readily convertible, at high efficiencies, into other energy forms, is readily transported, and nowadays is saleable by private generators in the UK. More recently the Non-Fossil Fuel Obligation (NFFO) has provided a mechanism for the payment of premium prices for electricity generated from renewable fuel sources. Hence electricity can command a high sale price.

Biomass fuels bulky: expensive to transport

Table 1 shows some characteristics of common fuels. Biomass fuels such as wood and straw have low energy densities: i.e. they are bulky and thus expensive to transport. The conclusion from this comparison is unsurprising, biomass is best converted near the point of production into a higher value commodity.

The bulk of electric power used in the UK is generated by means of steam plant. Thermo-dynamic and design factors limit the maximum overall efficiency of the best plant to about 40%, however this is at a multi-Gigawatt capacity. Fuel availability and logistics limit the maximum biomass-fuelled plant to tens of Megawatts, at which size the efficiency is in the low twenties of percent at best, and the capital cost per kilowatt is over £1000. Additionally, in order to maximise electrical generation efficiency, the waste heat is rejected at too low a temperature to be of practical use.

If a small on-farm steam-cycle unit were considered, fed by material from that holding, then the efficiency would be below ten percent in most cases. Thus it is apparent that a lower capital cost technology than steam, with a higher process efficiency would be desirable.

Liquifaction or gasification?

Generator sets, based on automotive-derived diesel engines and producing tens of kW, are readily available at reasonable cost, however they rely on distillate fuel for their operation. How then to use biomass fuel? The secret is to convert the biomass into a fuel the engine can use. The EC has supported extensive work into the liquefaction of biomass to produce petrol and gas oil type fuels, however such processes tend to require large process plant, needing substantial throughputs to be economic. Thus this offers little option for an on-farm process.

Table 1. Characteristics of some fuels for domestic use.

Fuel	*Cal value (lower) MJ/kg*	*Density as delivered kg/m³*	*Energy density MJ/m³*	*Price (£) per unit*	*per GJ*	*per m³*
Coal	33	1300	42900	150/t	4.55	195
Gas oil	42	835	35070	0.12/l	3.42	120
Wood	14	300	4200	27/t	1.93	8.1
Straw	14	150	2100	30/t	2.14	4.5
Electricity				0.07/kWh	19.44	

Prices are nominal – obviously location is critical – and reflect domestic levels of consumption rather than industrial

Thus we come full circle back to gasification. Vegetable-derived material heated in an oxygen-starved atmosphere will decompose to yield combustible gases, tars and char. In correctly designed apparatus, at high temperatures, the tars will decompose to yield gas, and so will the char, leaving only a small ash fraction. This process is well known: however, to produce a gas of adequate quality for an internal combustion engine is not easy.

Belgian work on gasification

To manufacture plant capable of running without constant attention has been the goal for many years. Hence it was that in September 1991 a party of interested people from the UK visited Belgium under the auspices of the 'Wood Energy Development Group', to view the latest Belgian work on gasification of solid-fuels to run i.c. engines.

Visits were made to the work of Yves Schenkel at Gembloux University, and then to Louvain University to see the work of Professor Martin. This article contains information based on verbal communic-ations with the workers, and the author's own observations.

Centre de Recherches Agronomiques Station de Genie Rural, Gembloux Dr Yves Schenkel

Gembloux is a Belgian Government research station, situated in the most agriculturally important area of Belgium. The Biomass group of the Agricultural Engineering department has been working on gasification for some time. Biomass for fuel is a new concept in Belgium, public bodies being more interested in new uses for classical crops, set aside not being popular in Belgium, due to high land quality. This department is 80% tropically orientated, but is pursuing biomass research in conjunction with other European countries.

Wood species not important

Thermochemical conversion of biofuels is perceived as being important to third world countries, and work at Gembloux has centred on evaluating fuels rather than gasifier or engine technology. In terms of wood, Beech and Spruce have been extensively tested, and Eucalyptus, Oak, Hornbeam and Birch to a lesser extent.

R Landen is a lecturer in the Machinery Department at Shuttleworth College, Old Warden Park, Biggleswade, Beds

Work has also been carried out on the formation of briquettes in a heated screw press, and their subsequent gasification, using nut shells, coffee husks etc. as feedstock.

The most salient finding is that wood species is not important, except for small density variations. The particle size and moisture content are the leading variables, the former being related to gasifier hearth size. Moisture contents up to 65% have been evaluated, 20% appearing to be a maximum figure.

Gasifier and Engine Uni

The gasifier observed was made by Touillet, feeding a Martezo spark ignition generating set, based on a Fiat 6 litre diesel unit. The engine is direct coupled to a 3-phase alternator rated at 32kW. The unit appeared to function happily at 20 amps per phase at 400V, the quoted maximun being 40A.

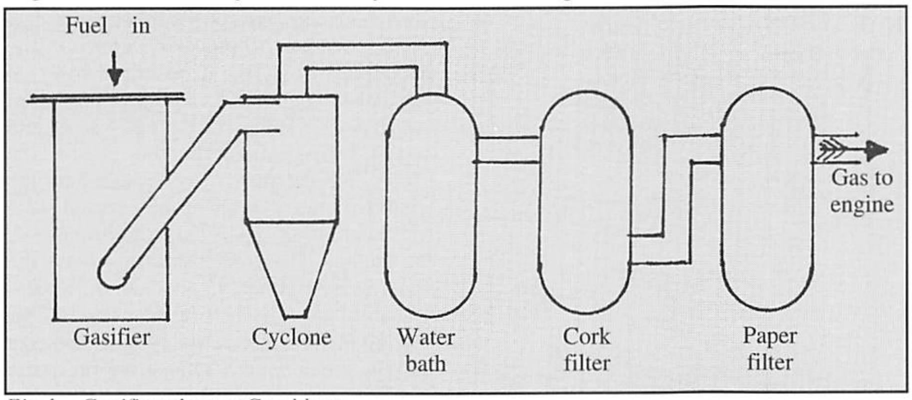


Fig 1. Gasifier plant at Gembloux.

The electrical power was being dissipated in a liquid resistance, with variable electrode immersion controlling the current. On increasing the load, approximately 30A was reached, followed by misfiring and stalling. An electronic governor system operating the gas and air butterflies was fitted, but seemed incapable of preventing considerable speed hunting, this being blamed on over-sensitivity of the governor. Observation, however, indicated that each hunting cycle was preceded by a rise in voltage, so a characteristic of the liquid resistance may be a more reasonable explanation.

The gasification equipment consisted of the hearth, being of the hand-fed, downdraft type, followed by a series of purification stages to provide clean gas for the engine. From the hearth, the gas passed through a cyclone, a water filter, a cork filter, and a paper filter for security. This is depicted in Fig 1.

The water has a service life of 10-15 days, collecting as it does most of the tar, the cork filter being washed regularly. The gas and air enter the engine via a simple pressure balance valve, to ensure the correct functioning of the succeeding gas / air butterflies, controlling engine output. This is depicted in Fig 2.

Regarding gasifier performance, roasted wood, overdried to an apparent minus 3-5% m.c., appears to be the best fuel, however it is claimed that with mc's up to 20%, all water present reacts with the charcoal, the only penalty being a reduction in gas yield. For charcoal gasification, the introduction of water is essential. Wood moisture contents up to 30% can be dealt with, however at the penalty of very high tar production, due to which weekly filter cleaning is necessitated. Work is envisaged into analysis of the tar, which contains a cocktail of unpleasant organic chemicals, ranging from the corrosive to the carcinogenic.

Typical fuel consumption is 130kgs per 4hrs – the maximum run time. The installation of comprehensive gas analysis and calorimetric equipment has produced extensive data. Typically, a good gas would be obtained 30 minutes after ignition, consisting of 20% CO, 15% H_2, 2-3% CH_4, <10%CO_2, the remainder being nitrogen. It is this nitrogen which limits the gas calorific value. The oxygen content should be zero, if it exceeds 1%, leakage of air into the gas system is indicated.

In French and Belgian experience, loose ash is produced in small quantities, clinkering not being a problem, however in the Sudan it has proved to be the reverse. This may well be due to high silica content in the fuel, which could also occur when gasifying Poplar coppice, as a result of the high bark content of small diameter stems.

Size of fuel material important

As discussed earlier, a definite interaction exists between the fuel and the gasifier sizes. Small material impairs airflow, leading to high tar production, and may be present in a predominantly large sized sample due to chipper characteristics or the inclusion of fine twigs. The latter could be problematic when handling coppice willow/ poplar, due to their being a large part of the plant by weight. Screening, perhaps at the chipper, is likely to be advantageous.

Large material can cause difficulties due to low surface area/volume ratios, and long gas paths.

Thus it can be seen that the mechanical rather than the varietal nature of the feedstock is of the greater importance.

Université Catholique du Louvain Professor Martin

Whereas the work at Gembloux has been predominantly fuel-orientated, that at Louvain is based far more on gasifier and engine design – i.e. the engineering perspective of the process. Various PhD students have been engaged on aspects of the project, under the direction of Prof. Martin, who appears to be extremely competent and enthusiastic about this area of work.

Laboratory facilities at Louvain are nothing short of superb, with a large hall equipped with a range of petrol, diesel, gas, and steam turbine engines, all fully instrumented.

The gasifier would normally be situated in the open air for safety reasons connected with CO leakage, however, in this case it is situated indoors, in a sealed room with fume extraction. The preferred fuel is wood chips dried to 8-10% under a controlled atmosphere.

Gasifier – special wood burning design

The design of the gasifier results from

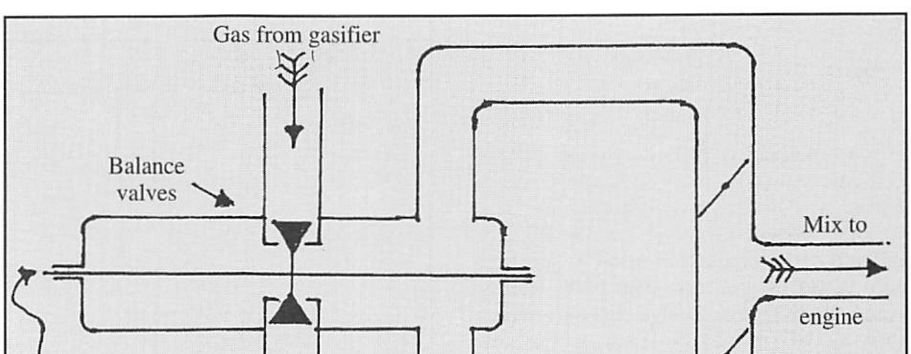


Fig 2. Gas/air balance valve and throttle butterflies.

original theoretical and practical work, carried out over a number of years. A mathematical model was constructed, based on heat conduction in the solid phase, earlier coal and charcoal work providing the reference information. However, it transpired that due to the high volatile content, wood behaves very differently to coal or charcoal. Gasifiers built on the latter lines, handling wood, produced much tar, and were found to have low temperatures in the oxidation zone – due to the processes there not being very exothermic, found to be caused by a deficiency of oxygen in the homogeneous reactions with the volatiles.

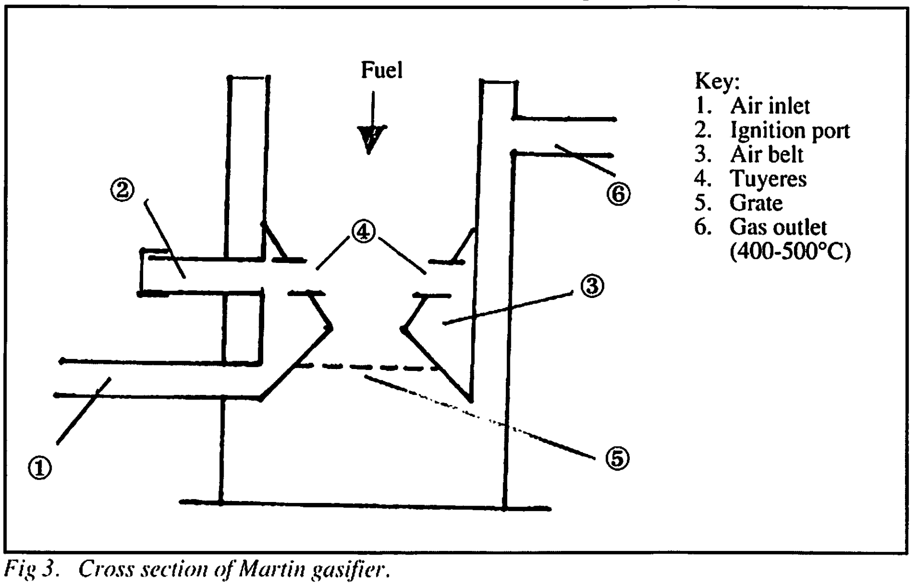


Fig 3. Cross section of Martin gasifier.

Charcoal experiences heterogeneous (i.e those of mixed phase, gas/solid) reactions: $C + O_2$; $C + H_2$. To obtain gas without the tar, complex organic molecules must be burnt, not cracked, which in turn requires high temperatures and sufficient oxygen in the oxidation zone.

As wood passes down through a downdraft gasifier, the stages are as follows:

1 – Drying
2 – Devolatisation
3 – Oxidation
4 – Reduction

The water vapour from the drying process is used chemically lower down, provided of course it is not excessive in quantity. The volatiles liberated in zone 2 are classically thought to be cracked in zone 4, splitting carbon chains and rings into more readily combustible forms. Recent research shows this view to be misleading, as the temperature in the reduction zone is of the order of 800C, inadequate to cause complete cracking of the tars during the short time they spend in this zone.

The alternative, as proposed by Prof. Martin, is to oxidise the tars at high temperature (12-1300C) in the gaseous phase, producing CO_2 and H_2O, and then reducing these products to CO and H_2, by reacting with the char in the reduction zone. The gaseous oxidation of the tars occurs when the surrounding char temperature is much lower, at about 800C. The reduction zone char is at a similar temperature to that at which the wood yields the tars, and thus cannot reasonably be expected to re-absorb them.

Pre-heated air gives high temperature for tar oxidation

Most commercial gasifiers are heading towards this process, but by chance rather than design. To facilitate high oxidation zone temperatures, Prof. Martin uses air preheated by passing it through a jacket surrounding the hot parts of the hearth – an analogous idea to that used in a blast furnace. A cross-section of his design is shown in Fig. 3.

Preheating the air is more effective than preheating the wood – the latter causes variation of gas composition during the firing of the batch: the first half being rich in H_2, from the volatiles, and the second in CO from the char. Flame stability in the oxidation zone is also improved by air preheating. Dry (10-15% mc) cold wood is thus the most satisfactory feedstock. The gas leaves the hearth at 600-650 C, preheating the air entering, cooling itself to 4-500C in the process. The hot air also helps with the endothermic reduction of water to H_2 and thus the tolerance to wider ranging moisture contents.

The air feed to the preheating belt is by a 2.2kW positive displacement blower, pressurising the gasifier to 4-500kPa to overcome system pressure losses rather than to supply supercharge to the engine. The gas leaving the hearth passes through an annular jacket to preheat the air, thence to a small cyclone to remove gross contamination, and is then bubbled through a small water bath to saturate the gas with water vapour. This stage also cools the gas by 80C. The wet gas passes now to an air cooled heat exchanger, whereupon the gas cools further to its dew point, forming droplets of water. On the principle of the rain-drop, these form on particulate matter, and cause it to fall out of suspension, leaving cool, clean gas. Liquid water drains out of the low end of the cooler, and the gas passes through a further small cyclone to remove water drops, to a trap containing wood chips and thence to the engine. The condensate returns to the water bath by gravity to maintain the level.

During the early part of the cycle the gas leaving the hearth is fairly cool, so does not pick up much water vapour from the water bath, but rather droplets: i.e a mechanical circulation. Significantly, these result in a flow of clean water from the cooler, which only becomes dirty once the gas is sufficiently hot to generate substantial evaporation. Thus it would appear that the condensation from the gaseous phase is vital for gas cleaning, rather than simple mechanical contact with water.

Fuel wood size again important

It has been observed that resinous wood does not necessarily form tar, but analogous to the findings of Gembloux on wood variety mechanical shape in relation to

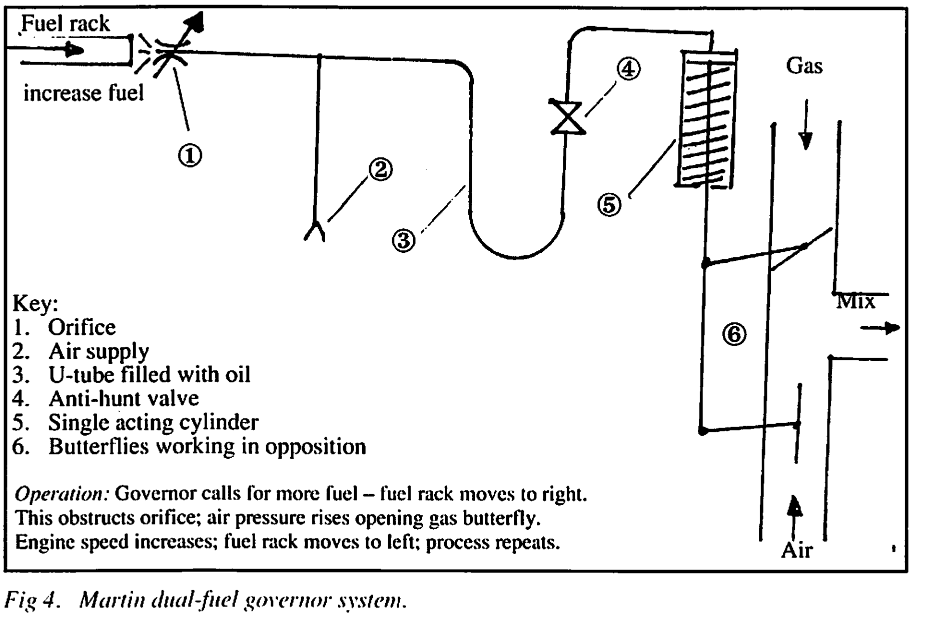


Fig 4. Martin dual-fuel governor system.

gasifier form is vital. The machine observed is at its optimum with 30-50 mm blocks, yet a heterogeneous sample with some long pieces is not thought to be problematic. The feed hopper can be as large as desired, the small one used being for ease of refuelling and probe insertion.

Lighting the gasifier

To light the gasifier an initial charge of charcoal is loaded, with wood above. A small port in the air belt, level with one of the tuyeres, is used to insert a gas jet until ignition occurs. At this stage it is preferable to use an extract fan to keep hearth pressure below atmospheric, as it is when refuelling the hopper, which should be done well before the hopper is empty. The grate is of the circular riddling type, and a 1-2% residue of charcoal ('the ash') is produced reliably.

The major safety risk is from CO, hence the gasifier should always be situated outside.

The early work at Louvain was done using charcoal as fuel, for which water addition, using a simple carburettor, is necessary. Without water, the gas is very hot as the reaction of the charcoal with the air is exothermic, whereas with water it is autothermic overall. The use of air/water mix superheated to 500C, analogous to the old blue water gas systems used for coal, resulted in a gas of c.v. 5500kJ/m^3 consisting of 35-36% CO, 10% H_2, the rest being N_2.

Dual fuel engine with modified governor

The engine is a Fiat 6cyl unit similar to that used at Gembloux, but retaining its fuel injection equipment, running as a dual fuel engine. An air/gas presure balance valve is used, again as at Gembloux, feeding a double butterfly unit, with the butterflies working in opposition. At full load an SI gas engine would receive 1:1 gas/air mixture, whereas this dual fuel unit runs on a 60% air:40% gas mixture at full load. This leaves sufficient air to burn the diesel pilot charge, which is 25% of the normal diesel charge when the engine is on full-load. The basic structure of the engine is completely unmodified.

The Bosch in-line injection pump is only modified in two areas. Firstly, the elements have been turned relative to the rack, so least injection is no longer zero, but instead that required to maintain combustion of the gas/air mixture. Secondly, the non-governor end of the rack has been uncovered to facilitate detection of rack movement as load changes. As shown in Fig. 4, a simple pneumatic system transmits the initial motion of the rack into an opening of the gas valve. Thus is the existing governor used to control the gas/air throttling, however, an electronic governor is planned.

The engine is started as a full-diesel, and the early gas from the hearth flared off. The engine was demonstrated accepting full-load 36KW) as a diesel, and then as a dual-fuel engine. It was noted that load was removed during the changeover. Slight hunting occured when running dual-fuel, this being reduced by the part-closure of a damping valve in the oil filled part of the gas valve circuit. The hunting was not of a severe nature, nothing approaching that noted at Gembloux, and was of higher frequency, perhaps 0.5Hz.

Instrumentation

The engine is equipped with computerised indicator apparatus on one cylinder, and fuel consumption measurement by the bizarrely crude (by comparison) pipette method! Provision is made for measurement of exhaust gas temperature of any of the cylinders to ascertain any unevenness in gas mixture distribution.

The indicator software appeared to be very user-friendly, and enabled real-time displays of pressure-volume, pressure-crank angle, temperature-entropy etc. to be made. Running as a diesel at 30kWe, a peak pressure of 7200 kPa was noted, and running as dual-fuel, 5600 kPa i.e. 80%. A notably increased delay period was observed in the latter case, presumably due to the lower fuel volume injected. The overall gasifier efficiency during the run observed was 78.4%, with wood to electricity conversion being 20%.

On switching from diesel to dual-fuel, a reduction in gas-oil consumption to approximately 30% of the original value was noted, the load remaining at 30kW.

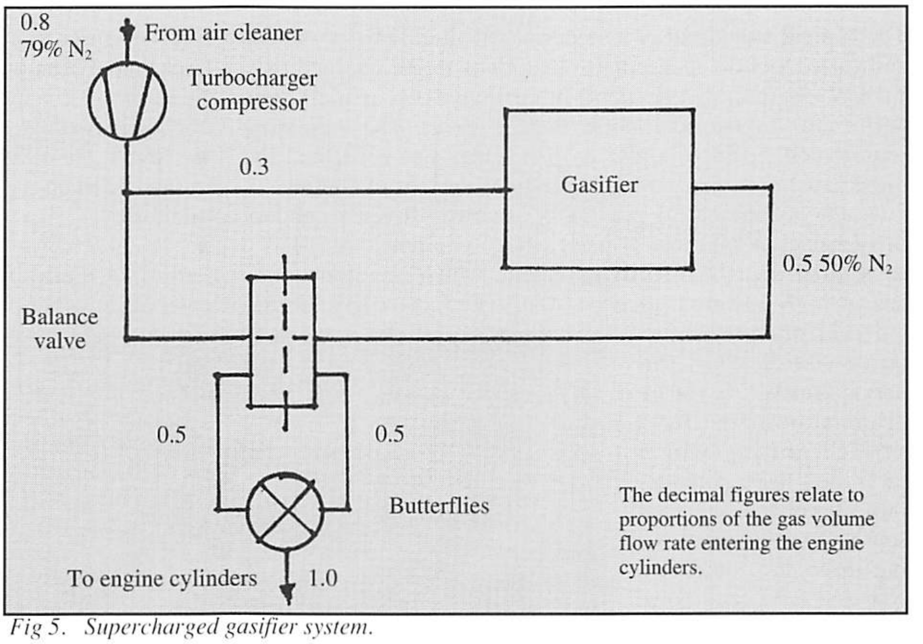


Fig 5. Supercharged gasifier system.

1 MW units should be possible

Professor Martin has ideas for supercharged units, where a proportion of the charge air is bled off into the gasifier, as shown in Fig. 5.

The increase in gas volume passing through the gasifier in only 80% of the normal volume flow through the turbo compressor, and due to the characteristics of this unit this results in increased boost pressure. Modelling of boost ratios up to 2 indicates that a wider power range is possible without mixture variations than is the case with naturally aspirated engines. Suck-through turbo systems are not satisfactory due to gas contamination – gas regarded as clean for the engine would be inadequate for the turbo. Pressure drop across the gasifier is of the order of 5% of atmospheric pressure.

In the following discussion, Professor Martin spoke of practical and theoretical work on mixture strength and injection volume. The engine observed operated on a pilot charge of about 25% of full-load rate, but a minimum of 4% can work, however ignition of non-stoiciometric mixtures becomes unreliable. A 'rule-of-thumb' is a rate corresponding to 60-70% of that required for high-idle. Very weak gas mixtures are then effectively being incinerated by a support fuel.

For practical application, Professor Martin suggests that 100kW is a good gasifier plant size, and up to 1MW should be possible with this type of down-draft unit. A small hearth size is necessary to permit rapid gasifier response to load fluctuations.

Trial unit at Enniskillen College

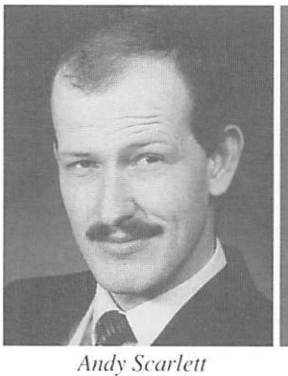
Professor Martin appears to have taken gasifier development further than any other small unit seen. The use of a dual-fuel engine is, in the author's opinion, a very wise choice, removing total dependence on gasifier operation for continuity of generation. Thus any disruptions to gas quality, especially at refuelling, need not have major impact.

A long-term trial of such a dual-fuel unit has been set up at Enniskillen College in Northern Ireland. If this is successful, it will provide firm evidence of viable applications for wood-chips etc. for electricity generation. This is needed to encourage the UK agricultural industry into supporting the concept of energy crops as an alternative.

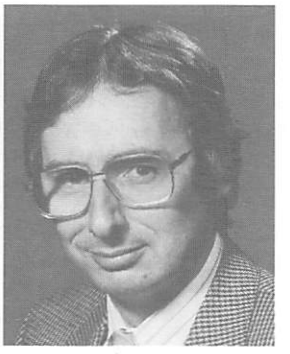
Development of the Suspended Rubber Track (SRT) tractor

Andy Scarlett and John Reed

Primary tillage still calls for tractors capable of generating substantial drawbar pull. This is too often synonymous with heavy weight and soil compaction. In this article the authors review the design and the initial field evaluation of positively-driven rubber track units developed to replace the rear driving wheels of a 75kW agricultural tractor and to generate high drawbar pull with minimum soil compaction.



Andy Scarlett



John Reed

The typical workload of a modern agricultural tractor is wide and varied, but the fact remains that many larger tractors (over 110kW engine power) spend more than 50% of their time performing tillage operations (Renius 1992). The increasing requirement to incorporate crop residues has redefined the importance of primary tillage operations such as ploughing.

Despite the increasing popularity of power-driven secondary tillage machinery, most primary tillage equipment still has a substantial draught force requirement, which necessitates the use of high-powered, heavy tractors. Unfortunately, during cultivation operations these vehicles have to drive across a large proportion of the field surface, during which time they have considerable potential to cause soil compaction, depending upon the local soil type and field conditions. The consequences of vehicle-induced soil compaction in terms of poor drainage, reduced crop yield and reduced fertiliser utilisation are well known.

Fig 1. Silsoe Research Institute Suspended Rubber Track (SRT) tractor.

Is it therefore possible to design a tractor which can generate the drawbar pull required to perform heavy cultivation tasks, whilst minimising the soil compaction it causes? This question prompted Silsoe Research Institute to commence a study of rubber track ground drive system performance characteristics in the mid-1980's.

Ground drive systems

In the past, ground drive systems comprised either pneumatic tyres or steel tracks, but during the last five years rubber tracks have been introduced onto the agricultural marketplace. The role of a vehicle ground drive system, be it wheeled or tracked is twofold:

- firstly, the weight of the vehicle must be transferred to the ground in such a way that sinkage and soil compaction are minimised;
- secondly, it must transmit mechanical energy from the vehicle's engine/transmission to the ground in order to generate drawbar pull.

The usual way to reduce the soil damage caused by compaction is to spread the weight of the vehicle over a larger area (assuming vehicle weight cannot be reduced), thereby reducing the ground pressure exerted. With wheeled vehicles this is typically achieved by fitting oversize (low ground pressure) tyres or dual wheels. Obviously there are practical limits to this approach.

Tracked vehicles potentially have a much larger ground contact area but the limited operating speed and inability of conventional steel-tracked vehicles to travel on roads has severely reduced their attractiveness.

In order to obtain optimum tractive performance from the wheeled ground drive systems of agricultural tractors, it is usually necessary to place additional weight on the driving wheels, in the form of ballast (Dwyer 1978). This does not correspond with the objective of reducing soil compaction. Conventional steel-tracked crawler tractors are able to generate high drawbar pulls at lower vehicle weights and do so more efficiently than wheeled machines (Osborne 1971). This,

Dr A Scarlett and N Reed are Research Engineers in the Mechanical Engineering Division of Silsoe Research Institute, Wrest Park, Silsoe, Bedford (Refereed paper).

together with their large ground contact area, permits tracklaying vehicles to perform heavy tillage work whilst causing less soil compaction than wheeled tractors.

Determination of tractive performance

Determination of vehicle tractive performance usually involves the measurement of coefficient of traction, slip and tractive efficiency in a range of field/soil conditions.

Tractive efficiency is the percentage of mechanical power input to the ground drive system which is made available at the tractor drawbar as drawbar power. It therefore directly represents the efficiency of the ground drive system.

The tractive performance characteristics of rubber track ground drive systems have been investigated by a number of workers. Many detailed investigations (Culshaw 1988, Dwyer *et al* 1990, Dwyer *et al* 1991), conducted with the aid of an instrumented test vehicle (Billington 1973), have identified the ability of rubber tracks to produce higher coefficients of traction than pneumatic tyres, at significantly lower slip values. However, the majority of rubber-tracked agricultural vehicles which are currently available are machines of high power and high mass, reminiscent of steel-tracked crawlers. The size of these machines has been influenced partially by the requirements of the markets for which they were developed and partially by the rubber track systems which they utilise.

The tractive performance of certain commercially-available rubber-tracked machines has been evaluated alongside that of large articulated four wheel drive tractors (Evans and Gove 1986, Esch *et al* 1990). The performance of the rubber-tracked vehicles was shown to be superior in terms of coefficient of traction, slip and tractive efficiency. Nonetheless these vehicles are not ideally suited to many European agricultural requirements.

This situation prompted the design and construction of rubber track units to replace the rear driving wheels of a 75kW tractor (Fig 1), in order to investigate the suitability of rubber track ground drive systems for agricultural vehicles of this size and to determine the factors which would constrain their use. Upon successful completion of the construction phase, an experimental programme was instigated to evaluate the behaviour and performance of the vehicle in typical agricultural conditions.

Design requirements

All previous rubber track performance investigations conducted at Silsoe Research Institute had utilised either a specialist instrumented test vehicle (Billington 1973) or proprietary non-agricultural tracked vehicles. With the benefit of the experience gained from these investigations, it was possible to compile a specification for a prospective rubber-tracked agricultural vehicle which, in the views of the researchers involved, would meet European agricultural requirements more closely whilst remaining economically attractive.

To limit engineering complexity and demands on resources, a design concept was chosen in which rubber track units would replace the rear driving wheels of a standard agricultural tractor of the 60-90kW power range. The design specification requested the following characteristics:-

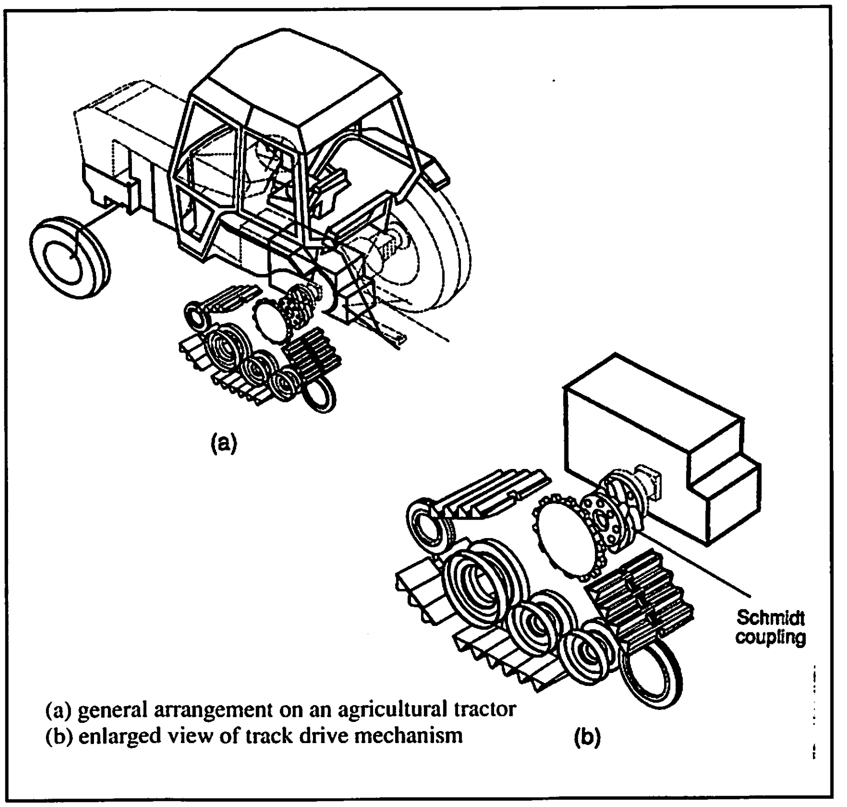
1. Track ground contact area to be at least twice that of the original tractor rear tyre size (*to reduce ground pressure to levels comparable with dual wheel equipment.*)
2. Ability to transmit heavy draught loads (*to take full advantage of the improved tractive performance characteristics which rubber tracks had previously demonstrated.*)
3. Provision of a suspension system capable of permitting operation at typical wheeled tractor speeds without compromising ride quality.
4. Track unit width to allow in-the-furrow ploughing and rowcrop work (*to permit unrestricted agricultural use where at all possible.*)
5. Provision to incorporate instrumentation for experimental test purposes.
6. Units to be as light as possible (*to restrict total vehicle weight and therefore ground pressure exerted.*)

Conceptual design

The conceptual stage of the track unit design was influenced by three main considerations:-

1. The requirement that the track units should readily fit a conventional 75kW tractor, e.g. a Ford 7610.
2. The choice of whether to use a positive drive (sprocket and embedded link) or friction drive type of rubber track.
3. Designing a suspension system which could transmit high draught force without inducing undesired suspension displacement.

One of the problems of designing a track unit for a standard tractor is achieving a convenient transfer of drive from the existing rear axle position down to ground level. It appeared, initially, that one solution might be to use a chain or gear transmission to transfer power from the axle down to a ground-contacting track sprocket. However, the weight and



(a) general arrangement on an agricultural tractor
(b) enlarged view of track drive mechanism

Fig 2. Initial track unit design concept cost of such high torque transmissions would have been prohibitive. The only practical alternative was to consider methods by which the track itself could be used for directly transmitting the drive. This had the effect of limiting the realistic track geometry options to those which could encompass the axle position and make ground contact directly below it. Meeting both these criteria meant that only a small angle of sprocket/pulley wrap (80-90°) would be available for drive transfer. This necessitated the use of a positive drive rubber track.

Having defined the type of track and its preferred spatial envelope, it was then necessary to investigate various suspension/drive system concepts. Three basic ideas emerged.

The first (Figs 2a & b) was based on the concept of using a single degree of freedom (vertical) suspension system to support a fixed-geometry track unit. Sprocket drive would be obtained, via a Schmidt coupling, from the normal tractor rear axle flange. The main problem proved to be the limitations imposed by the Schmidt coupling drive (Fig 2b). It was expensive, heavy and required unacceptably high standards of shaft parallelism. This led to the investigation of a second concept, in which relative movement would be allowed between an axle-mounted drive sprocket and independently-sprung track idlers and ground roll units. Unfortunately, despite the basic simplicity of the concept, it did not lend itself to this application, the main problem being lack of space in which to fit appropriately sized, independent suspension units. Serious problems were also expected with draught force/suspension system interactions.

Final design

The final track unit arrangement (Fig 3) features four key elements:-

1. An axle-mounted drive sprocket (a)
2. A single subframe (b), to carry all the track idlers and ground roll units
3. A parallel link, air spring suspension system (c), which is insensitive to drught load variations.
4. A novel track tension compensation system (d) (British Patent Application No. GB 2239-847-A)

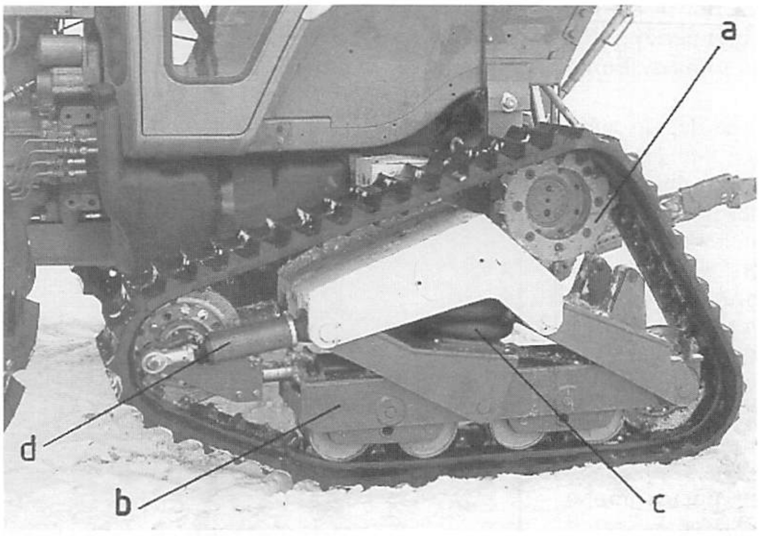


Fig 3. Final design of track unit.

– track type and drive configuration

A positive drive rubber track, manufactured by the Bridgestone Corporation, was selected with the track driving sprocket (Fig 3a) fitted in place of the normal tractor rear wheel. In-the-furrow operation (Fig 1) was permitted by specifying a track width of 400mm. An inter-track width setting of 1829mm (centre to centre) was selected, this being typical for a wheeled tractor of this size. The track length and pitch were 4680mm and 90mm respectively. The difference in diameter between the 14 tooth track sprocket and the normal tractor driving wheel meant that, in order to achieve normal tractor operating speeds, it was necessary to increase the axle half-shaft speed by a factor of 4.5. This was conveniently accomplished by removing the epicyclic final drive reduction gearing from the tractor rear axle. The track units were fitted to a four wheel drive tractor so that, in the unlikely event of losing a track, braking capability would be retained from the front wheels.

– ground rolls, idlers and subframe

Four closely-spaced, bogie-mounted rollers, working in conjunction with the rear track idler, form the ground running elements of the track (Fig 3) and provide a ground contact patch length of approximately 1070mm. The use of closely-spaced small rollers helps to spread the vehicle mass along the track contact patch as evenly as possible, minimising local variations in ground contact pressure. All the track engaging idlers and ground roll units, other than the main drive sprocket, are connected to a common subframe (Fig 3b) which provides the stable base required by the suspension system, to effectively support the tractor.

– suspension system

One of the objectives of the project was to produce a rubber-tracked tractor which could operate at speeds and ride quality levels at least equal to those of a wheeled tractor. This was achieved by use of the parallel link, passive air spring suspension system (Fig 3c).

The suspension system is virtually immune to draught force interactions, by virtue of its parallel link geometry. The latter was designed so that the angle of the parallel links (relative to the horizontal) approximately bisects the angle formed by the track around the rear idler (see Fig 4). When the draught force increases, it causes a corresponding increase in local track tension on either side of the rear idler. The resultant of these tension forces passes via the idler into the rear suspension link, as shown in Fig 4. Providing the link bisects the track angle as described, the force is reacted along the line of action of the link and therefore has no component which would tend to rotate the link, thereby causing a change in suspension ride height.

The complications associated with lateral roll stability, which may possibly have necessitated active ride height control, were avoided in this prototype by the selection of relatively stiff suspension characteristics, similar to those of a conventional tractor rear tyre. The vertical travel of the system (136mm) was however in excess of that which could be achieved with a conventional agricultural pneumatic tyre.

It was considered aesthetically and practically important that all the track suspension components should remain within the outside profile of the track. Whilst this led to a neater design, it severely restricted the space available for the spring. However, by use of an air spring (Fig 3c) this problem was surmounted. Not only was the air spring capable of storing more energy than an equivalent sized mechanical spring, its wide range of mounting options and the fact that its load capacity and/or rate could be readily altered, made it an ideal choice for this application.

– track tension compensation system

Significant track tensioning problems can occur when track suspension systems are specified which allow substantial relative movement between the track drive sprocket and the other track elements. The problem can be explained by reference to Fig 4. As the suspension system deflects (under an increasing load) the parallel links rotate and the tractor moves forward and down, relative to the ground rolls. This reduces the theoretical track length required to wrap around the whole assembly. Since the actual track length is constant, some device is required to take up the slack and maintain a reasonably constant track tension.

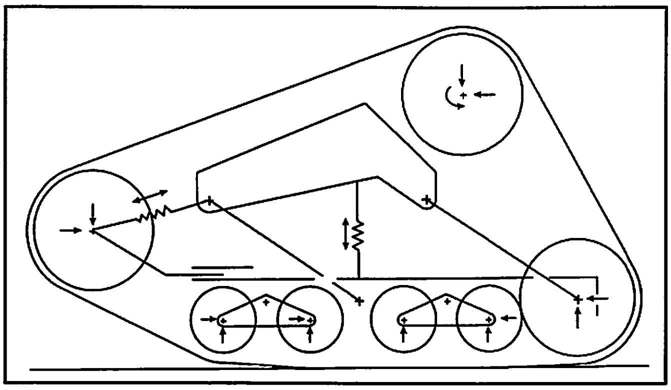


Fig 4. Typical forces acting upon the track unit.

The problem was overcome by use of the track tension compensation system shown in Fig 3(d). It consists of an idler assembly which is constrained to move linearly along a slide, mounted on the front of the subframe (Fig 3b). The horizontal position of the idler is determined by a pair of spring-loaded links connected back to the tractor structure. As the suspension system compresses, the change in geometry between the tractor body and the subframe causes the spring-loaded links to force the idler along its slide, thereby maintaining track tension.

By careful choice of the idler/springlink/slide geometry, it was possible to maintain a near constant track tension, over the full range of suspension movement, with hardly any springlink length variation.

Static force analysis

Following the selection of the final design concept, considerable static force analysis was conducted in order to determine the likely levels of loading to which the track unit components would be subjected during operation. This was considered an important, integral part of the design process.

This analysis not only assisted the choice of materials and components during the design and construction of the track units, but also permitted determination of any likely suspension system instability in any of the chosen loading conditions. In this instance, suspension instability was considered to be undesired movement of the suspension system due to unforeseen force interactions, resulting in unpleasant or even potentially dangerous vehicle behaviour. Typical examples would be changes in suspension ride height in response to variations in vehicle draught loading, emergency braking or hard cornering.

The analysis highlighted possible flaws in the initial suspension geometry chosen and minor modifications were made. Further analysis suggested that there was no longer cause for concern; the operating behaviour of the track units subsequently validated these predictions.

SRT tractor performance

In order to evaluate the behaviour and performance of the SRT tractor, a substantial programme of testing is planned. Areas to be investigated include tractive performance, steering and handling, manoeuvrability, ride vibration, ground surface disturbance, practical operating restrictions and, in due course, long term design durability.

The tractive performance of a 75kW four wheel drive tractor, fitted with oversize tyres and ballasted for optimum traction, was evaluated alongside that of the SRT tractor. It was not considered appropriate to conduct the comparison against a tractor fitted with standard tyres, previous work having indicated that the latter are usually too small for optimum tractive performance (Dwyer 1978).

The tractive performance of each vehicle has been determined in a range of field conditions, which so far have included cultivated clay, ploughed and rolled sandy clay loam and sandy clay loam stubble, by the use of a load car vehicle. The latter is capable of applying various levels of drawbar pull to a test tractor, over a range of forward speeds.

During testing, microprocessor-based instrumentation recorded the drawbar pull, true forward speed, engine speed and theoretical forward speed of the test tractor. From this information, values of slip and drawbar power were calculated. By loading each tractor in a number of transmission gear ratios, representing a forward speed range of 3.2-12.0km/hr, the tractive performance characteristics of each vehicle were determined (Fig 5).

It is planned to investigate tractive performance under a wider range of field conditions in the future.

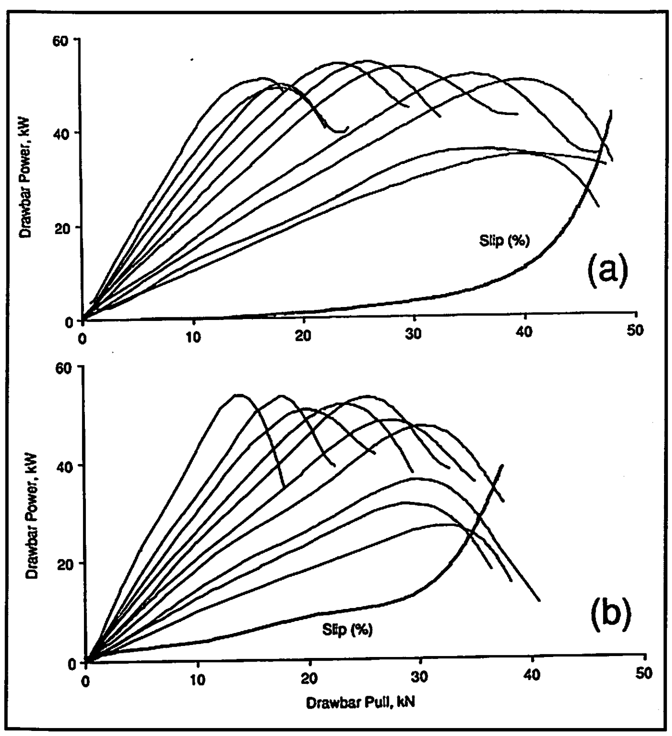


Fig 5. Tractive performance of (a) SRT tractor and (b) wheeled tractor, in a range of transmission gear ratios.
Soil type:– ploughed and rolled sandy clay loam.
Soil moisture content:– 14.0% (mean). Dry bulk density:– 1400 kg/m³

Fig 5 shows the SRT tractor to be capable of generating up to 30% more drawbar pull than the wheeled tractor under identical field conditions. The slip of the SRT tractor is also significantly lower for any given level of drawbar pull, typically 4-6% compared with 11-13% for the wheeled tractor.

Unfortunately the rolling resistance of the SRT tractor was found to be greater than that of the wheeled tractor, reducing the maximum drawbar power available to approximately 53 kW: effectively the same as the wheeled tractor. This equates to a tractive efficiency of approximately 75%, both tractors having a max. p.t.o. power of 70kW.

However, despite this apparent impediment, the overall tractive performance of the SRT tractor is superior by virtue of the fact that this level of drawbar power is made available over a wider range of drawbar pulls, enabling the vehicle to perform high draught tasks more effectively.

In practical terms this means a 75kW SRT tractor can easily handle a five furrow reversible plough in almost all soil types.

New track design reduces rolling resistance

If the tractive efficiency of a ground drive system can be improved, a greater proportion of engine power can be effectively transmitted to the ground and made available to pull implements, resulting in improved vehicle performance.

The initial performance of the SRT tractor was encouraging in terms of coefficient of traction and slip, but unfortunately its tractive efficiency did not exceed that of the wheeled tractor. This shortfall in performance was attributed to the excessive rolling resistance of the rubber track system, the latter being largely due to the energy required to bend the track around the track unit idlers and drive sprocket during track motion.

The track manufacturers therefore constructed a new set of rubber tracks, designed specifically for this application. Although identical in external appearance, the rolling resistance characteristics of the new tracks were significantly different. The coefficient of rolling resistance of a 75kW wheeled tractor, fitted with standard tyre equipment, was measured on a smooth concrete track. Similar measurements were performed on the SRT tractor, fitted in turn with the original and new rubber tracks (Fig 6).

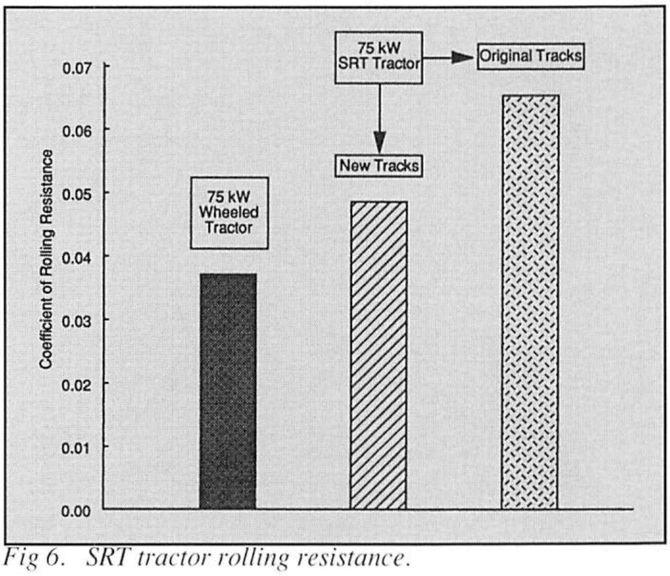


Fig 6. SRT tractor rolling resistance.

The new tracks exhibited a 26% reduction in coefficient of rolling resistance, compared with their predecessors. The coefficient of rolling resistance of the wheeled tractor was still lower, but it is likely that this disparity would reduce substantially when operating on a softer field surface. The effect which the lower rolling resistance of the new tracks will have upon the field tractive performance of the SRT has yet to be evaluated, but expectations are high.

Conclusions

The availability of rubber tracks has permitted the consideration of vehicle designs which combine the tractive performance and low ground pressure advantages of a conventional crawler, with the high speed (32km/h) on-road capability of a standard wheeled tractor.

Tractors which utilise rubber track ground drive systems appear capable of better tractive performance than equivalently-powered wheeled machines of similar weight. Also, by virtue of their larger ground contact area, rubber track systems should exert a lower ground pressure, thereby reducing the degree of soil compaction caused.

A further potential benefit is the possibility of developing a much lighter vehicle, which would exert even lower ground pressure, whilst retaining adequate tractive performance. This is possible due to the ability of a rubber track system to efficiently generate sufficient traction without the need for excessive ballast. Consequently, if future changes in vehicle design permit a reduction in weight, ground pressure could be reduced still further, thereby largely avoiding soil compaction.

The degree of soil compaction caused by both existing and experimental ground drive systems needs to be investigated and it is hoped to study this aspect in the future. However the possibility of achieving traction without causing compaction is now very real.

Acknowledgements

The authors gratefully acknowledge the contribution of Mr John Knox (Silsoe Research Institute) during the design and construction phases of this project, the financial support of the Ministry of Agriculture, Fisheries and Food and the significant material assistance provided by the Bridgestone Corporation, Firestone Industrial Products Co., Ford New Holland Ltd and Michelin Tyre plc.

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Prospects for Industrial Fuelwood Supply and Utilisation

"We know how to grow the trees. We also know how to burn the biomass produced. It is the link between the trees and the boiler where the agricultural engineer has a major role to play if woody biomass is ever to become a significant energy resource."

This is the theme of New Zealand authors, Ralph Sims and Peter Handford. Their article will appear in the next issue of Agricultural Engineer

Design and management of automatic milking systems Part II

by Toby Mottram

In Part I of this three part review Toby Mottram showed how the addition of labour saving devices in the milking parlour has tended to make the work monotonous with a small number of tasks having to be repeated frequently. Further automation is now desirable to allow the skills of the herdsperson to be better deployed and to promote improvements in management and higher yields.

Part I dealt with the problems of bringing in the cows and positioning them for milking. In this issue Toby Mottram now reviews the prospects for automation of the actual milking operation.

The final part of the review will cover the benefit, in information gathering and herd management that will be made possible by an automated milking system.

Once the animal is positioned the next task is to prepare the teats for milking. These are two separate tasks, ensuring that a minimum of environmental contaminants enter the human food chain and examining the teats for evidence of disease or damage. Teat preparation, including the removal of foremilk is also an important element in the stimulation of the cow's milk ejection reflex. It is not clear if this has an effect on the lactation yield of the cow (IDF 1987).

Teat preparation - care to avoid injury and bacterial transfer

Mechanical methods of cleaning cow's teats with rotating nylon brushes have been demonstrated in prototype form (Wesselink 1991, Mottram 1992a). There are doubts about the acceptability of such devices being used on a routine basis for frequent milking. The forces applied need to be large enough to remove encrusted dried faeces but not so great as to abrade the skin.

Any cleaning device should try to minimise the transmission of pathogens between teats on the same cow and between cows, this would tend to eliminate devices which operate on all teats simultaneously. Manual teat preparation has been shown to be a major source of transmission of pathogens (IDF 1987).

It is probable that, in the majority of farm situations in the UK, the teats are first inspected, and only cleaned if they are visibly dirty.

Cleaning, which is usually by washing the teats with warm water and drying with a paper towel, removes contaminants which would otherwise be drawn into the milk but has major disadvantages. Teats subjected to regular wetting develop skin sores and chaps (Phillips *et al* 1981). Wetting of the teats increases the risk of pathogens colonising the teat end (Grindal and Bramley 1989). Washing without drying will not reduce the total bacterial count over that which would have occurred had the teats not been cleaned at all (Cousins and McKinnon 1979).

Cleaning a cow's four teats takes 15s for a human (Cousins & McKinnon, 1979) and reduces the output of the milker. Even cleaning the two teats of goats takes a mean of 3s (Mottram *et al* 1991). In general, the teats of goats and sheep are considerably cleaner than those of cows due to the low moisture content of the faeces of these species. Teat preparation of cows might also be eased by reducing the moisture content of the diet, which might also have nutritional benefits (Webster 1987) and reduce the contamination of teats by splashes of faeces.

Automatic teat inspection system essential

Cows' teats should only be cleaned to remove visible contaminants in line with good industry practice. Thus the development of an automatic teat inspection system is an essential element in the further development of automated milking system (Mottram 1990).

Not only must teats be inspected for dirt but also for damage, for example, it is hard to imagine a worse fate for a cow than for a rotating nylon brush to be applied to an open wound. Mottram *et al* (1991a) applied to patent a device the size of a teat cup which could be offered up to individual teats by a robot arm. An array of LEDs shone light onto the surface of the teat and measured the reflectance signal. It was claimed that the reflectance of the surface of a dirty teat would differ from that of a clean teat. Work is continuing on this device at Silsoe Research Institute.

Before full automatic milking can be contemplated it would seem to be essential for a reliable method of inspecting and cleaning teats to be developed. Otherwise, automatic teat cup attachment could only be contemplated where an operator is present to inspect and clean teats, perhaps in an entry race to a rotary parlour.

If an inspection only system were available, dirty or damaged teats need not be milked and the herdsperson notified.

Foremilk examination - may be unnecessary

There is a legal requirement to discard foremilk in the UK. However, the effect of drawing foremilk has not been shown to be beneficial in controlling mastitis except as a means of detection (IDF 1987). If mastitis can be detected in other ways then the examination of foremilk may be ignored in further automation of the milking process.

T T Mottram is an agricultural engineer employed by the Welfare Science Division of Silsoe Research Institute to develop the science supporting automatic milking systems (refereed paper).

Teat cup attachment – problems still, but working methods expected with time

Attaching teat cups to an animal is a simple task for a human operator but at the limits of the capabilities of robotics. Several systems are in development at various centres, Table 2 (Frost 1991, Mottram 1992a). Schillingmann and Mottram (1992) and Frost *et al* (1992) reported a success rate varying from 45% to 85% successful attempted attachments. Information on the other systems is in the form of publicity material which is not reliable (Mottram and Street 1991a).

The key features of all the successful robots are;

- a database of historical teat positions,
- a global position finding system and
- a local sensing system.

The problem is not yet totally solved but the amount of investment both financial and in terms of reputation is sufficient to ensure that working methods of teat cup attachment are likely to be developed over the next few years.

Table 2. Automatic milking system developers

Lead Institution	*Associates*	*Country*	*Expected launch*
Silsoe (SRI)	IAH	UK	1997
Prolion	IMAG,Wageningen	NL	1995
Gascoigne	NRS, Lelystad	NL	1995
Duvelsdorf	FDRC, Kiel	D	1995
FAL[1]	University of Braunschweig	D	–
CEMAGREF[2]	Prolion	F	–

Note: 1. FAL – Forschungsanstalt fur Landwirtshaft
2. CEMAGREF – Centre National du Machinisme Agricole, du Genie Rural, des Eaux et des Forets.

The main divergence in design is between systems where four teat cups are carried under the udder together (Gascoigne, Prolion) and those where single teat cups are carried beneath the cow and attached in series (Silsoe, Duvelsdorf). The former offers the possibility of a shorter total attachment time but with the disadvantage of a heavy mechanism held beneath the cow; the latter offers the advantage of simplicity and cleanliness with a disadvantage in total attachment time due to the need to return to pick up teat cups.

By 1991 no robot had been demonstrated operating on more than one stall. However, it has been suggested (Jakobson and Rabold 1985) that a teat cup attaching robot could travel between the stalls of a tandem milking parlour, much as a human milker. This would allow the robot to utilise the time available whilst each cow milked to attach teat cups to other cows. With a work routine time of 120s, such a robot could be capable of milking 30 cows per hour.

Milking - no changes in cups and liners

The essential elements of the design of the milking machine have changed little in the past fifty years. A vacuum is applied to the animal's teat by means of a flexible tube contained within a rigid chamber. The annular space between the rigid wall of the chamber (teat cup) and the flexible tube (teat cup liner) is pulsated between vacuum and air pressure. Milk ejected from the teat is drawn away from the teats through a manifold (cluster) to a recorder jar or milk pipeline.

The milking machine has been studied over many years to improve the milking characteristics and the current state of the art has been well reported by Thiel and Mein (1979).

National (BS5545) and international (ISO5707) standards govern the construction of milking machines.

It is unlikely that automatic milking will bring significant changes in the design of teat cups and liners although changes may occur in milk transport and in the control of the milking process. None of the robot systems demonstrated to date has used a conventional clawpiece. The removal of the clawpiece may have effects on the characteristics of the milking cycle. This is an area of new work but can be based on many years of empirical research.

The milking process was once seen as a major factor predisposing cows to mastitis. Considerable effort has been made in improving the design of milking machines. An experimental technique was developed and used in the UK at NIRD and later at Milking and Mastitis Centre, AFRC Institute for Animal Health, Compton to investigate the effect of milking machine changes on pathogenesis of infection (Neave *et al* 1968). Teats of cows were challenged with a treatment of pathogens to identify the effects of various machine and hygiene techniques on the susceptibility of cows to mastitis.

As a result of these and other studies, the chief aims of milking machine design have been in reducing cross contamination of teats with pathogens, the precise control of the pulsation features and the prevention of high velocity jets of milk striking the teat end.

Milking machine designers have also attempted to maximise the rate of flow of milk away from the cow so as to minimise the time that the cow spends in the parlour and to reduce the vacuum level used. This has been achieved by larger bore short milk tubes, better clawpiece design, low level milk pipelines and optimised pulsation rate and ratio.

Mastitis control remains important but automation should not increase incidence

However, any successful research and development programme begins to suffer from the law of diminishing returns. Where the technique under test had only a slight effect on mastitis control very large numbers of cows were needed to ensure a statistically valid result.

Grindal and Hillerton (1991) examined the data which had been collected over a number of years. Groups of cows were classified on flow rates which had been milked with three different treatments, with no teat disinfection.

Despite the massive bacterial challenge, slow milking quarters were hard to infect even under the worst possible conditions (no pulsation or shields). On the other hand, 36% of the fast flow rate quarters developed clinical mastitis even under the best possible machine conditions (pulsation plus shields). Under the worst machine conditions (no pulsation or shields) virtually all the high flow rate quarters became infected.

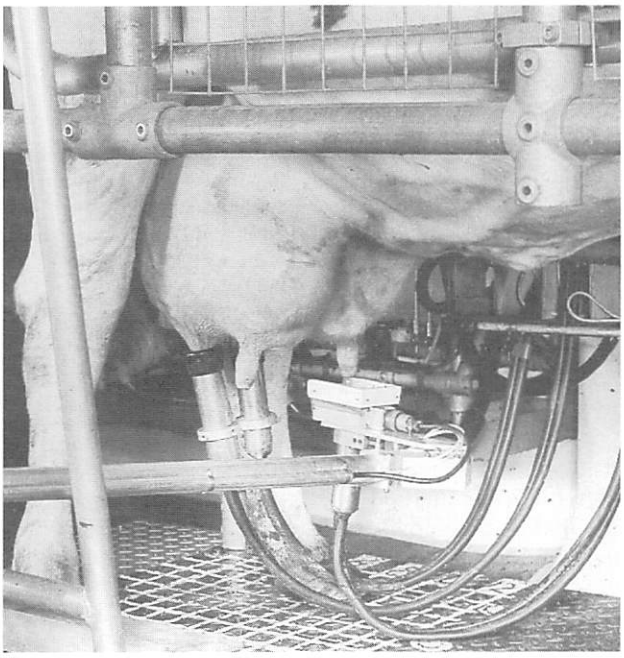
The results show that although machine parameters are important, teat patency (ease of milking) has considerable significance. A slow milking cow milked with poor equipment was less likely to get mastitis than a fast milking cow milked with efficient equipment.

Cows have been bred for faster milking yet the incidence of new infections particularly those associated with the milking machine have been reduced in absolute terms (Hillerton 1992). Grindal & Hillerton (1991), concluded "..results strongly suggest that the benefits of reduced infection from mastitis control are significantly underestimated as animals now appear considerably more susceptible than 40 years ago".

Increasing the numbers of milkings per day may reduce mastitis but increase teat damage. Hillerton (1991) reported that increasing the frequency of milking reduced the rate of new infection, probably through the mechanism of flushing invasive bacteria from the teat duct. Trials were conducted without teat disinfection and it might be supposed that more frequent teat disinfection would also have a beneficial effect.

To investigate the suggestion that frequent milking might increase teat lesions Hogewerf *et al* (1991) built a device to capture an image of the teat end, however, results are not yet available on this possible effect.

It is a reasonable assumption that the automation of milking, using the machine characteristics currently employed in best conventional practice is not likely to leadincreased incidence of mastitis. The emphasis on breeding cows with high flow rates has been caused by batch milking in herring-bone parlours. Where the cow is treated as an ind-ividual as in a tandem or abreast layouts the need for fast milking is diminished and where frequent milking is used it seems likely that the incidence of mastitis might be reduced.



The Silsoe Research Institute robotic arm attaching teat cups.

Stripping not necessary

Traditional dairy practice always dictated that residual milk should be routinely 'stripped' from the udder by hand or machine to prevent mastitis and to stop cows drying off but there is little evidence to support this practice (Kingwill *et al* 1979 Webster 1987). Animals from which only 75% of the milk has been removed had an inhibited secretion to 75% of normal but leaving 0.5 kg reduced lactation yields by 3% (Dodd and Griffin 1979).

The lactating mammal secretes milk continuously and stores it within the udder, in alveoli and cisternal structures. Milking removes the stored milk from the udder but the milk secretion continues. The teat cups are removed from the animal when milk flow falls below a level which has been established by practice to indicate the end of milking. Milking machines have not yet been developed sufficiently to extract all the milk available in the cisterns.

The many complex variables influencing the rate of flow of milk from the teat are not the subject of this review, however, a brief discussion is necessary to describe two automated methods of teat cup removal.

Towards the end of milking, flow from the teat becomes restricted and the teat cup tends to rise up the teat (Thiel and Mein 1979). It thus becomes difficult for the milking system to extract the remaining milk, or strip yield, from the udder. This effect can be countered by increasing the downward force on the teat cup. Thiel and Mein showed that increasing the normal weight of a cluster assembly by 1.8 kg decreased the amount of strip yield from the udder by 0.4 kg.

However, increasing the vertical load on the teat cup always increases the risk of the teat cup liner losing adhesion and slipping down the teat. Air can then enter the mouthpiece reducing vacuum and accelerating milk towards the ends of the other teats. The cluster weight is therefore a compromise between the need to prevent the teat cups creeping up the teats and the teat cups falling off.

Automatic cluster removal already commonplace

The removal of the teat cups was seen as a skilled task which needed attention to ensure that the cows were milked out. This view was still supported by Webster in 1987. However automatic teat cup removal on the basis of reduced milk flow has been commonplace since the sixties without any obvious deleterious effects. The principal effect of automatic cluster removal is to allow one person to handle many more milking points and thereby increase the number of animals milked peroperator (Smith 1985). It also allows the operator to leave the milking parlour for extended periods without a risk of overmilking.

Automatic cluster removal

The components of automatic cluster removal systems were described by Goldsmith (1980). They consist of a timer, a means of sensing the flow of milk, and a device for reducing the vacuum and pulling the cluster from the cow to a rest position.

The flow sensor, which is sometimes combined with automatic milk recording meters or jars, detects when the flow of milk falls below a set level (commonly 200 ml/min) and triggers the reduction of vacuum and removal of the cluster. The timer overrides the flow sensor until enough time has elapsed for the cow to have responded to stimulation and flow to have started. These systems are based on flow of milk from the udder and rely on the milking system removing as much milk as possible without downward force being added at the end of milking.

Horton (1982) reported an automatic cluster removal system based on processing a signal from a strain gauged beam milk recorder jar. Mottram *et al* (1991b) described the development of an improved automatic cluster removal system. This sensed the difference between the cessation of milk flow due to the liner slipping and the true end of milking. This was achieved by monitoring the rate of flow. Liner slip was shown to temporarily raise the flow of milk at the sensor by the effect of air entering the milk line at the teat cup. Milk flow then appeared to cease. By analysis of the flow information it was therefore possible to reduce the risk of teat cups being removed whilst the operator was trying to reposition them.

Mottram *et al* (1991) also added safeguards against equipment failure. In the event of the flow sensor failing to send a signal when flow has fallen below a set level an animal can be grossly overmilked, particularly if an operator is not present. To overcome this the timer was set to trigger removal after a fixed period. In addition, if the recorder jar filled with milk the system could also be triggered to remove the teat cups and empty the jar, thereby removing the risk of milk entering the vacuum line.

An alternative method of automatic teat cup removal with mechanised machine stripping has been developed by Icking (1984) and reported by Dethlefsen *et al* (1990). Stripping is achieved by pulling the clawpiece down 40 mm when the flow has reduced to 1000-800 ml/min. Teat cups are removed when milk flow has reduced to 200 ml/min. It was claimed that conventional automatic teat cup removal extended milking time and reduced milk yields by failing to remove strip yields.

New techniques and further research in cluster removal and teat disinfection

With the introduction of automatic milking, new techniques of teat cup removal have been suggested. The robot arms which attach teat cups in series (FAL, Silsoe, Duvelsdorf) use conventional teat cups but no cluster. This allows the teat cup to be withdrawn into a holder or magazine by a force applied along the milk line.

In the Silsoe system the milk from each teat is taken to a separate recorder jar and the decision to remove each teat cup is made on the basis of flow from that teat alone. There is no overmilking of faster milking teats. However, the removal of the clawpiece has removed the loading of the teat cup which Thiel and Mein indicated was important for the removal of strip yields (1979). Butler (1991) has suggested that an alternative to loading the teat cup would be to reduce the force drawing it upward. This might be achieved by reducing vacuum towards the end of milking. Alternatively, the teat cups could be withdrawn downwards and a force applied by means of the removal mechanism. Whichever method of removal is applied, the monitoring of milk flow, preferably on a per quarter basis, is the only method of accurate feedback control.

Methods of teat cup removal for automatic milking need further research to ensure that there are adequate safeguards for the welfare of the animal against machine failure and to ensure acceptable milk extraction with a lightly loaded teat cup. It also remains to be seen whether frequent milking counters any tendency for milk secretion to be inhibited by the small amounts of strippings remaining in a poorly milked out udder.

It has been shown that applying teat disinfection immediately after milking significantly reduces mastitis infection (IDF,1987). In conventional systems this is best achieved by dipping or spraying the teats in a solution of disinfectant. However, there is some evidence that teat spraying is less effective than dipping, if only because it is less easy to do correctly (Shear, 1984).

A device for disinfecting teats within the teat cup at the end of milking was tested by Thompson *et al* (1976) but proved less effective than dipping.

Walk through sprayers have been shown to be an effective method of teat disinfection, but must be used immediately after milking (Shearn 1984). Electrostatic methods of teat spraying have been suggested (Miller 1992) but these have yet to be evaluated fully.

Automating the 'exit' still a problem

In conventional parlours the movement of animals from the parlour is ensured by supervision and sometimes encouragement by the operator. Relatively simple technologies have been developed aimed at simplifying the exit of animals. In herringbone layouts these include blocking the access to feeding managers, lifting the entire manger assembly or increasing the number of sides as in the 'Trigon' so as to reduce the number of animals moving at any one time.

Automating the exit of the animal may pose more of a problem than getting the animal to enter a milking stall. It is axiomatic that if an animal has been attracted by a pleasant stimulus then she is unlikely to voluntarily abandon that stimulus unless a greater stimulus affects her perception of her needs. Winter (private communication, 1992) has suggested that timid cows may hide from aggressive animals in a voluntary milking stall.

Since it is undesirable that the efficiency of an automatic milking system should be compromised by dozing cows, new research is needed to ensure that cows exit in a reasonable time.

The concluding part of Toby Mottram's review will be published in our next issue.

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Palm tree oil: petrol blends for IC engine fuels

Both palm kernel oil and palm oil mix easily with petrol at room temperature and below. Edward Baryeh here reports on experiments to assess the suitability of such oil:petrol blends as fuel for internal combustion engines. From measurement of various key properties in mixes of different proportion of oil to petrol he concludes that, in general, the palm kernel oil blends have superior qualities compared to the palm oil blends. A 50:50 blend seems likely to give a good and economic compromise. Higher ratio blends may also be used if internal combustion engines can be modified in their design to handle the blend properties. Further investigation is needed to evaluate the characteristics and efficiency of engines using these and other blends.

Fuel cost for internal combustion engines has been on the increase for the past 15 years especially in the non-oil producing developing countries.

A litre of petrol in some non-oil producing West African countries costs as much as 70 pence. Some of these countries spend as much as half or more of their foreign exchange imports on oil. There is therefore an obvious need to search for means of reducing this heavy foreign exchange expenditure. Life in these countries will be better if some of this foreign exchange can be diverted for other essential amenities like good drinking water, rural electrification and good health care services. Moreover, this will reduce their dependence on the diminishing fossil energy supplies of the world.

The use of vegetable fuels in internal combustion engines dates back to 1900 (Baldwin, Cochran and Daniel, 1981). Since then, other studies have been conducted by Zubik, Sorenson and Goering (1984), Bruwer (1980), Baldwin, Cochran and Daniel (1981) and Strayer, Copworth and Copiuk (1980) on sunflower oil fuels, sunflower oil, soyabean oil and canola oil respectively. No studies like the one presented here have been made to date on palm kernel oil and palm oil blends which are exclusive to the tropics.

Good calorific values

The studies presented here investigate the properties of palm kernel oil and palm oil blends with petrol for possible use in internal combustion engines. Palm kernel oil is used in West Africa for cooking, body lotion (medical use) and fuel. With a calorific value of 41,500 kJ/kg, it is promising as a vegetable oil:petrol blend for internal combustion engines. Palm oil is used extensively for cooking and soap manufacturing. It has a calorific value of 38,750kJ/kg which makes it also promising as a vegetable oil:petrol blend for internal combustion engines.

Professor E A Baryeh is Professor of Agricultural Engineering at ESIE, BP 311 Bingerville, Ivory Coast (refereed paper)

Production and use of palm tree oils

Palm tree varieties and their production as crops are outlined by the Crop Research Institute (1974). The tree produces two distinct types of oils: one from the nut itself called palm kernel oil and another from the fibrous part of the nut called palm oil.

To obtain **palm kernel oil**, the nuts are cracked, the kernels in the nuts are fried, milled and boiled. The oil is then skimmed from the top of the boiling mass.

To obtain **palm oil** there are two traditional methods:-

– boiling of the fruits, pounding and reboiling. The oil (edible oil) is skimmed from the top of the boiling mass; or

– fermenting the fruits in pits, pounding and extracting the oil by hand. This oil which is not edible is used for soap manufacturing.

Modern methods use steam boilers, hydraulic presses and centrifuges.

The oils used for the investigations were produced by the modern method by the State Farms Corporation in Ghana. The oils mix easily with petrol. Their compositions are given in Table 1.

Investigation of key properties

Palm kernel oil and edible palm oil manufactured as outlined

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above were filtered and each oil was blended with petrol in the proportions of 0,15,30,45,60,75,90 and 100% of palm kernel oil or palm oil.

Table 1. Composition of palm kernel oil and palm oil.

	Palm kernel oil	*Palm oil*
Saponification	245-255	196-205
Iodine value	19	53
Refractive index at 40°C	1.450	1.455
Unsaponiable matter	1.0%	1.0%
Free fatty acid	4.0%	3.0%
Moisture and volatiles	0.15%	0.15%
Insoluble impurities	0.05%	0.05%

Source- Food Research Institute, Accra, Ghana.

The **specific gravity** of each blend was determined five times with a constant weight hydrometer at a room temperature of 29°C. Hare's density apparatus may also be used (Sears, Zemansky and Young, 1976).

Surface tension is the ratio of the surface force on a fluid surface to the length perpendicular to the surface along which the force acts. This was measured by breaking the blend-air interface with a 25mm diameter metal ring tensiometer using a torsion balance type of instrument. Five measurements were made for each blend at 29°C. It was important to clean thoroughly all glassware and tensiometer with benzene or methylated spirit between measurements. The surface tension (S) is given by:

$$S = \frac{F}{\pi d} \quad \text{N/m} \qquad (1)$$

Where F = force on ring (N);
d = ring diameter(m)

A `U' shaped wire, slider and film method may also be used (Sears, Zemansky & Young 1976).

The **calorific value** of a fuel is the amount of heat energy produced by the complete combustion of unit weight of the fuel. This was determined five times for each blend using a bomb calorimeter. Eastop and McConkey (1990) have discussed this method extensively.

The **cetane numbers** of the blends were evaluated using reference mixtures of cetane ($C_{16}H_{34}$) and α-methyl-naphthalene ($C_{11}H_{10}$) according to the standard test methods outlined by the Institute of Petroleum Standards for Petroleum and its Products (1984).

The **pour point**, the lowest temperature at which the fuel can be poured, was not determined because tropical temperatures are not low enough to make such an investigation necessary.

The **viscosity** of a fluid is a measure of its resistance to flow. The coefficient of viscosity, η (also called **dynamic viscosity** or absolute viscosity) is defined mathematically as:

$$\eta = \frac{\tau}{V} \text{ centipoise} \qquad (2)$$

Where τ = shear stress (η/m^2); V = velocity gradient (s^{-1}).

When the fluid density, ρ is included in the definition, the result is termed **kinematic viscosity**, υ, defined mathematically as:

$$\upsilon = \frac{\eta}{\rho} \qquad (3)$$

The rotating Couette flow method (Tritton, 1977) was used to assess the coefficient of viscosity. Six velocity gradients were imposed on the blends using concentric cylinder type viscometer (Tritton, 1977). Temperature variation was achieved using a constant temperature bath. Temperatures were measured with copper-constantan thermocouples. The viscosity is then calculated from the formula:

$$\eta = \frac{T(a_2^2 - a_1^2)}{4\pi a_1^2 a_2^2 (\Omega_2 - \Omega_1)} \qquad (4)$$

Where T = torque on each cylinder (N-m);
a_1 = radius of inner cylinder (m)
a_2 = radius of outer cylinder (m)
Ω_1 = angular velocity of inner cylinder (rad/s)
Ω_2 = angular velocity of outer cylinder (rad/s)

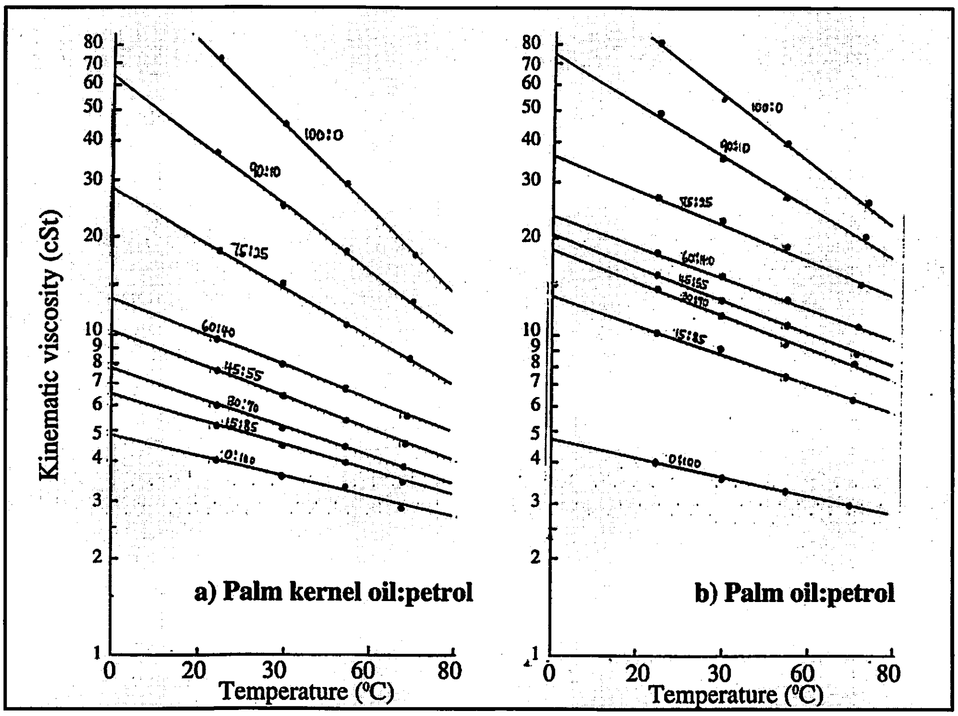

Fig 1. Kinematic viscosity versus temperature: a) palm kernel oil:petrol blends, b) palm oil:petrol blends.

Alternatively the falling sphere method can be used (Tritton, 1977) or the Standard Saybolt Universal Viscometer can be used (Woodruff and Lammers, 1977). The kinematic viscosity is then evaluated using equation 3 and the specific gravity values already found.

Results and comments – the blends look promising for IC engine fuels

Tables 2 and 3 show the fuel properties for palm kernel oil:petrol and palm oil:petrol blends respectively.

For both fuel blends, the **specific gravity** increases with increasing percentage of vegetable oil indicating that both oils are heavier than petrol. Palm kernel oil:petrol blends have higher specific gravities compared to corresponding palm oil:petrol blends.

In general, the specific gravities are within the range that can be handled by internal combustion engines. By interpolation it is seen that the specific gravities for palm kernel oil:petrol ratio of 45:55 and palm oil:petrol ratio of 51:49 are equal to that of diesel fuel which internal combustion engines are known to handle well.

The **surface tension** also increases with increasing percentage of vegetable oil from 25.0 to 33.4 N/m for the palm kernel oil:petrol blends and 25.0 to 32.9 N/m for palm oil:petrol blends. This may be due to the fact that petrol is lighter than both oils.

Table 2. Palm kernel oil:petrol blend properties.

Blend %oil	*Specific gravity*	*Surface tension (N/m)*	*Calor value (kJ/kg)*	*Kinematic visc (cSt)* 25°C	40°C	55°C
0	0.770	25.0	47,200	4.0	3.6	3.3
15	0.809	28.6	46,650	10.5	9.1	7.6
30	0.831	30.1	45,700	14.1	11.6	9.9
45	0.851	31.0	44,885	15.5	12.8	10.8
60	0.870	32.3	44,050	18.1	15.4	13.0
75	0.884	33.0	43,200	26.8	22.5	19.1
90	0.899	33.2	42,250	49.0	35.8	27.5
100	0.910	35.4	41,500	82.0	55.2	39.5

The **calorific value**, however, decreases with increasing percentage of vegetable oil. This is to be expected since petrol has a higher calorific value than any of the vegetable oils. For a vegetable oil:petrol ratio of 60:40, the calorific values of palm kernel oil blend and palm oil blend reduce by only 6.7% and 12.6% respectively.

This indicates that the fuel blends are promising as fuel for internal combustion engines. This effectiveness of course reduces as the percentage of the vegetable oil increases.

Table 3. Palm oil:petrol blend properties.

Blend %oil	*Specific gravity*	*Surface tension (N/m)*	*Calor value (kJ/kg)*	*Kinematic visc (cSt)* 25°C	40°C	55°C
0	0.770	25.0	47,200	4.0	3.6	3.3
15	0.797	26.5	44,000	5.2	4.5	4.0
30	0.821	27.7	43,000	6.0	5.1	4.5
45	0.841	28.7	42,135	7.7	6.4	5.4
60	0.858	30.0	41,250	9.6	8.5	6.6
75	0.873	30.8	40,400	18.3	14.4	10.8
90	0.888	31.2	39,500	36.2	25.1	18.2
100	0.898	32.9	38,750	72.6	45.2	30.0

The **cetane number** of the palm kernel oil:petrol blends varied from 25 for 15:85 blend to 42 for 90:10 blend at an engine speed of 2500 rpm, while the cetane number variation for the same ratios of palm oil:petrol blends was 22 to 40. At 50:50 blend ratio, the palm kernel oil blend yields a cetane number of 39, while the palm oil blend yields 37. These values are comparable to the cetane number value of 40 for medium speed engines cited by Eastop and McConkey (1990).

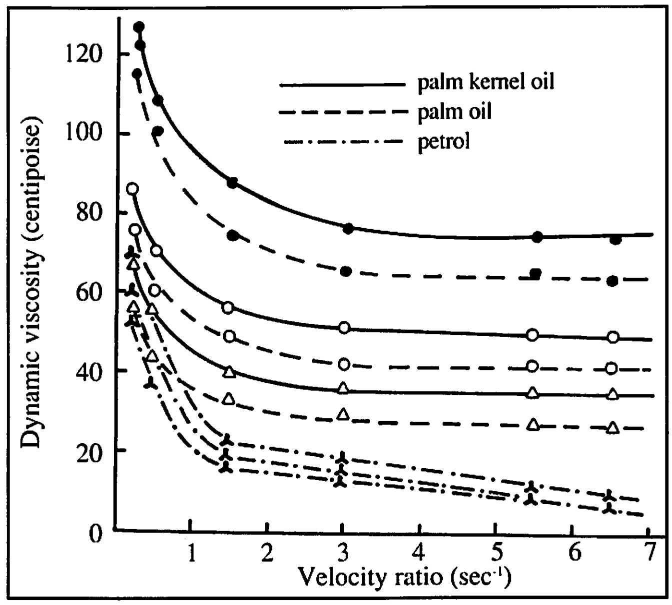

Fig2. Dynamic viscosity against velocity gradient

The tables indicate that the **kinematic viscosities** increase with increasing percentage of vegetable oil at any given temperature. They also show that at any blend, the viscosity reduces with increasing temperature. These variations are, however, not linear.

Figs 1(a) and 1(b) show plots of kinematic viscosity of palm kernel oil blends and palm oil blends respectively against temperature on semi-log (linear-log) axes. The figures show a linear relationship between kinematic viscosity and temperature. This suggests a relationship of the form:

$$\upsilon = e^{\alpha\theta} + \beta$$

Where θ = temperature (°C)

α and β = constants depending on blend.

The graphs converge as the temperature increases. The kinematic viscosity for palm kernel oil:petrol blends varies between 4.8 and 175 cSt at 0°C to between 2.7 and 8.0 cSt at 100°C For palm oil:petrol blends the variation is between 4.8 and 180cSt at 0°C to between 2.6 and 17cSt at 100°C.

The **dynamic viscosities** of palm kernel oil, palm oil and petrol are plotted against velocity gradient for three different temperatures in Fig 2. The increase in viscosity with decreasing

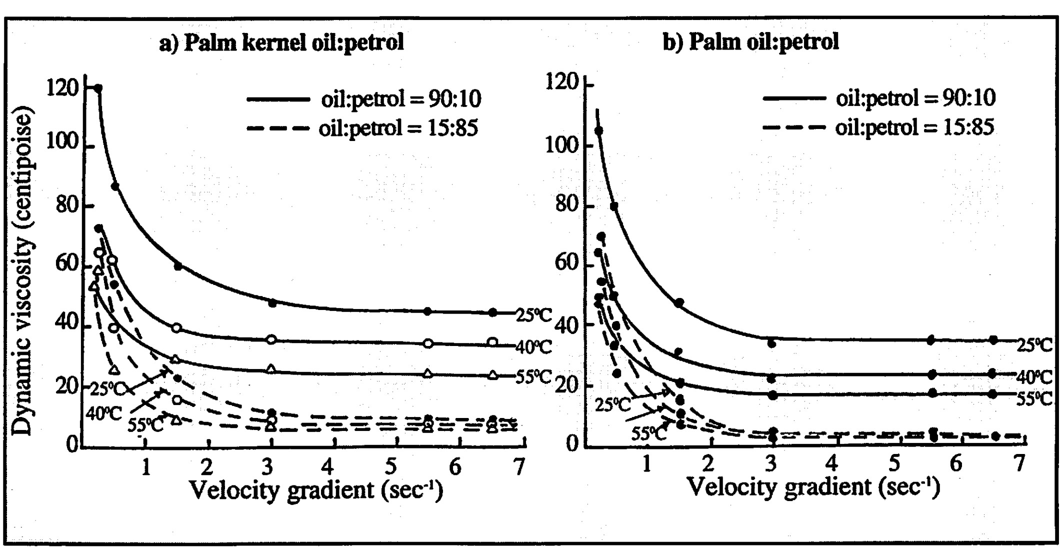

Fig3. Dynamic viscosity against velocity gradient; a) palm kernel oil:petrol , b) palm oil:petrol.

temperatures is evident. Viscosity decreases sharply with increasing velocity gradient up to about 3.5 sec^{-1} velocity gradient for palm kernel oil, 3.0 sec^{-1} for palm oil and 1.7 sec^{-1} for petrol. After these, palm kernel oil and palm oil viscosities are practically constant as velocity gradient increases. For petrol, viscosity continues to decrease with increasing velocity gradient but in a gentler manner. This could be due to the fact that petrol is lighter and less viscous compared to the vegetable oils.

Results for the various blends exhibit intermediary values. This is displayed in Figs 3(a) and 3(b) for two palm kernel oil:petrol blends and two palm oil:petrol blends respectively. The figures display a low and a high vegetable oil percentage blends. Both figures show higher viscosities for blends with higher vegetable oil percentage as expected. Fig 3(a) indicates that the palm kernel oil:petrol blends behave as a non-Newtonian fluid when the velocity gradient is less than 3.25 sec^{-1}. Newtonian behaviour is exhibited when the velocity gradient is larger than 3.25 sec^{-1}. Fig 3(b) also shows that palm oil:petrol blends behave as a non-Newtonian fluid for velocity gradients less than 2.75 sec^{-1} and behave Newtonian for velocity gradients larger than 2.75 sec^{-1}.

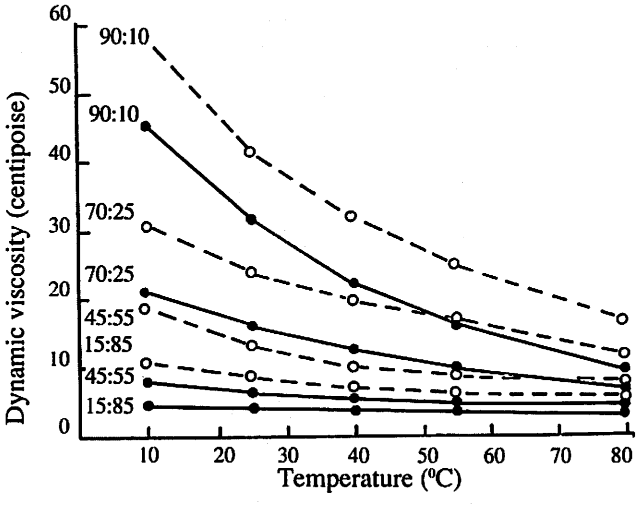

Fig 4. Dynamic viscosity against temperature

The figures depict that the viscosities change considerably with temperature and velocity gradient. This is also apparent when the viscosity is plotted against temperature for different blends. Fig 4 demonstrates this for four blends of each of the two vegetable oils. The figure again shows the convergence of the graphs for increasing temperatures. At temperatures up to 40°C, the viscosity variation with temperature is very acute, the acuteness increasing with increasing percentage of vegetable oil. Beyond 40°C however, the viscosity variation with temperature has a gentle slope. (Not easily seen in Fig 1).

A 50:50 blend looks a good balance but engine performance still to be assessed

The results suggest that at about 50% palm kernel oil or palm oil blend, it is possible to strike a compromise between the various fluid properties while obtaining a reasonably high fuel blend calorific value for internal combustion engines. This ratio will permit the use of the blends in internal combustion engines.

According to Jones et al (1990) and Baldwin, Cochran and Daniel (1981), it is possible to run IC engines on 80:20 blend of coconut oil:diesel blend and 70:30 blend of soyabean oil:diesel blend respectively. However, coconut is a coastal crop which does not do well in forest regions. Soyabean is more temperate than tropical. The palm tree is a forest crop and can be cultivated more extensively in the more vast forest regions compared to the coconut tree. Hence, palm kernel and palm oils are more available in the tropical forest regions than coconut and soyabean oils. Palm kernel oil and palm oil can be produced cheaply and they do not deplete.

It is therefore obvious that there will be a saving in time and money while employment will be provided at the same time if more palm trees are grown to make such blends for use in internal combustion engines.

Conclusion

Both palm kernel oil and palm oil mix easily with petrol at room temperature and below. The mixability around freezing temperatures was not investigated because this does not pose any problems in the tropics.

The higher the palm kernel oil content of the blend, the higher the specific gravity, surface tension and viscosity for a given temperature, while the calorific value decreases. The viscosity also depends on the velocity gradient. The cetane number also increases with increase in palm kernel oil content of the blend at the chosen speed of operation. These conclusions are also true for palm oil blends. In general, however, the palm kernel oil blends have superior qualities compared to the palm oil blends.

A 50:50 blend seems likely to give a good and economic compromise. Higher ratio blends may also be used if internal combustion engines can be modified in their design to handle the blend properties.

Further investigation is needed to evaluate the characteristics and efficiency of engines using these and other blends.

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Water management and conservation in the Somerset Levels andMoors

–report on the field meeting of the Soil and Water Management Specialist Group, 23rd October 1992

More than 30 participants joined this very successful visit to the Somerset Levels and Moors, organised on behalf of the Soil and Water Management Specialist Group by Henry Gunston of the Institute of Hydrology, Wallingford.

From the top of Burrow Mump, the small but distinctive hill by the confluence of the rivers Parrett and Tone, we looked out on flat, watery landscapes which had known King Alfred at Athelney, the armies of the Duke of Monmouth and King James II at Sedgemoor and, for the romantic, possibly King Arthur at Glastonbury.

Our guides for the morning, Martin Tidy of ADAS and David Ayers of MAFF Flood Defence Division, set the scene and distinguished between the inland 'moors', where peat predominates, and the slightly higher 'levels' on marine clays nearer the coast.

Drainage of Levels and Moors

From Burrow Mump our first stop was the National Rivers Authority (NRA) Curry Moor pumping station, beside the river Tone. Here David Ayres outlined the history of drainage on the Levels and Moors, where threats of flooding came as much from the sea as from the river systems of the Axe, Brue and Parrett. Although clyses (tidal sluices) and rhynes (drainage channels) had been used since the Middle Ages, drainage disputes between the great landowning religious houses had not always been conducted with true Christian charity!

When drainage pumping was discussed, it was appropriate that we were standing in the building at Curry Moor which houses the preserved 1864 Easton & Amos Drainage Machine, a twin cylinder steam engine driving the vertical shaft of an Appold centrifugal pump. One of the station staff operated the electric motor which turns over the engine machinery, and a similar engine can be seen in steam at the nearby Westonzoyland pumping station.

Today - water level management

Following the move from steam to diesel to electric pumps, and increased investment since the 1930s on flood defence structures, the emphasis on the Levels and Moors has shifted from 'land drainage' to 'water level management'. Martin Tidy picked up this theme in his description of the operation of the MAFF Environmentally Sensitive Areas (ESA) scheme. This is designed to conserve the landscape and its wildlife habitats by keeping the traditional pattern of grassland farming, and ensuring that the rhynes are managed in ways that helps aquatic plants and animals.

Farmers are asked not to cut or disturb the grass at certain times of the year so that birds can find food and shelter there. The use of chemical sprays is controlled, and farmers taking part in the scheme also agree to pollard their willows reularly; normally every five to seven years. Takeup of the initial ESA by farmers has been good, and a modified scheme is now being brought into operation.

Having seen the Ruston diesels and the electrically powered Archimedes screw pump at Curry Moor, we moved west to Hook Bridge on the Tone to visit a concrete siphon which takes drainage water under the river channel. West again at New Bridge we saw the sluice which is normally the tidal limit of flow in the Tone.

Conservation - all interests involved.

As well as the ESAs, there are a range of other inputs to conservation on the Levels and Moors. The NRA Wessex Region, which controls the major pumping stations, has developed a water level management and nature conservation strategy. In addition, as well as local farmers, English Nature, the Fnvironment Department of Somerset County Council, Internal Drainage Boards and local naturalists groups are also involved.

The Royal Society for the Protection of Birds also has a major interest, through its West Sedgemoor reserve, which comprises some 1,100 acres of wet grassland and 100 acres of woods. This was our destination after lunch, and Les Street, the RSPB reserve manager, took us out onto West Sedgemoor. The grassland is managed as far as possible on a traditional system for haymaking and grazing, with high water tables maintained to encourage flooding during the winter.

The RSPB reserve is now the only remnant of the Levels and Moors, holding large numbers of certain special breeding and wintering birds, as well as having the largest area of waterflower meadows in England.

The RSPB reserve at West Sedgemoor - 1200 acres of grassland and woodland - is managed on a traditional system for haymaking and grazing. It is now the only remnant of the Levels and Moors.

Silsoe College ecology projects

The day ended with presentations by Gordon Spoor and David Gowing on the Silsoe College work on West Sedgemoor.

One project, linked with the Institute of Terrestrial Ecology station at Monks Wood, has been to study the effects of maintaining different water table levels on the variety of plant species, and to quantify the actual water regime requirements of these species. Once these requirements have been quantified improved water management procedures can be introduced on more marginal reserves to improve conditions for the desired plant populations and bird species. In addition, this data will be particularly useful in environmental impact assessments to help assess which species are likely to disappear or could potentially colonise following any water regime change.

Silsoe College has also a large sub-irrigation/drainage project on West Sedgemoor, identifying the water management practices necessary to provide optimum conditions for breeding waders during the April-June period and for grass cutting and grazing from July onwards. A section of the project is concerned with developing low cost pipe and mole drain systems to provide the required subsurface pipes at minimum cost.

Our thanks go to ADAS, English Nature, Institute of Hydrology, MAFF, NRA, RSPB, Silsoe College - and the very friendly staff of the Rose & Crown, East Lyng - for their contributions to this successful visit.

See also 'The re establishment of Wetland habitats' by John Sheail, Institute of Terrestrial Ecology, *Agric Engr* 47(3) 71-73.

Agricultural mechanisation – strategy formulation

Clare Bishop and Joe Morris

Experiences in sub Saharan Africa

Agricultural mechanisation is one ingredient in the process of developing not only a country's agricultural sector but also its manufacturing base. Experiences in practice have been mixed. Abandoned machinery, mixed equipment inventories, and inconsistent policies are all testimonies to the *ad hoc* approach to introducing mechanisation.

Strategy formulation reviews both the demand and supply components of the agricultural mechanisation system, as well as the wider policy environment and institutional setting. The output of this process is the identification of a suite of programmes and projects which together address the future agricultural mechanisation needs in a country.

In this paper the authors comment on their experiences of strategy formulation in countries in sub Saharan Africa.

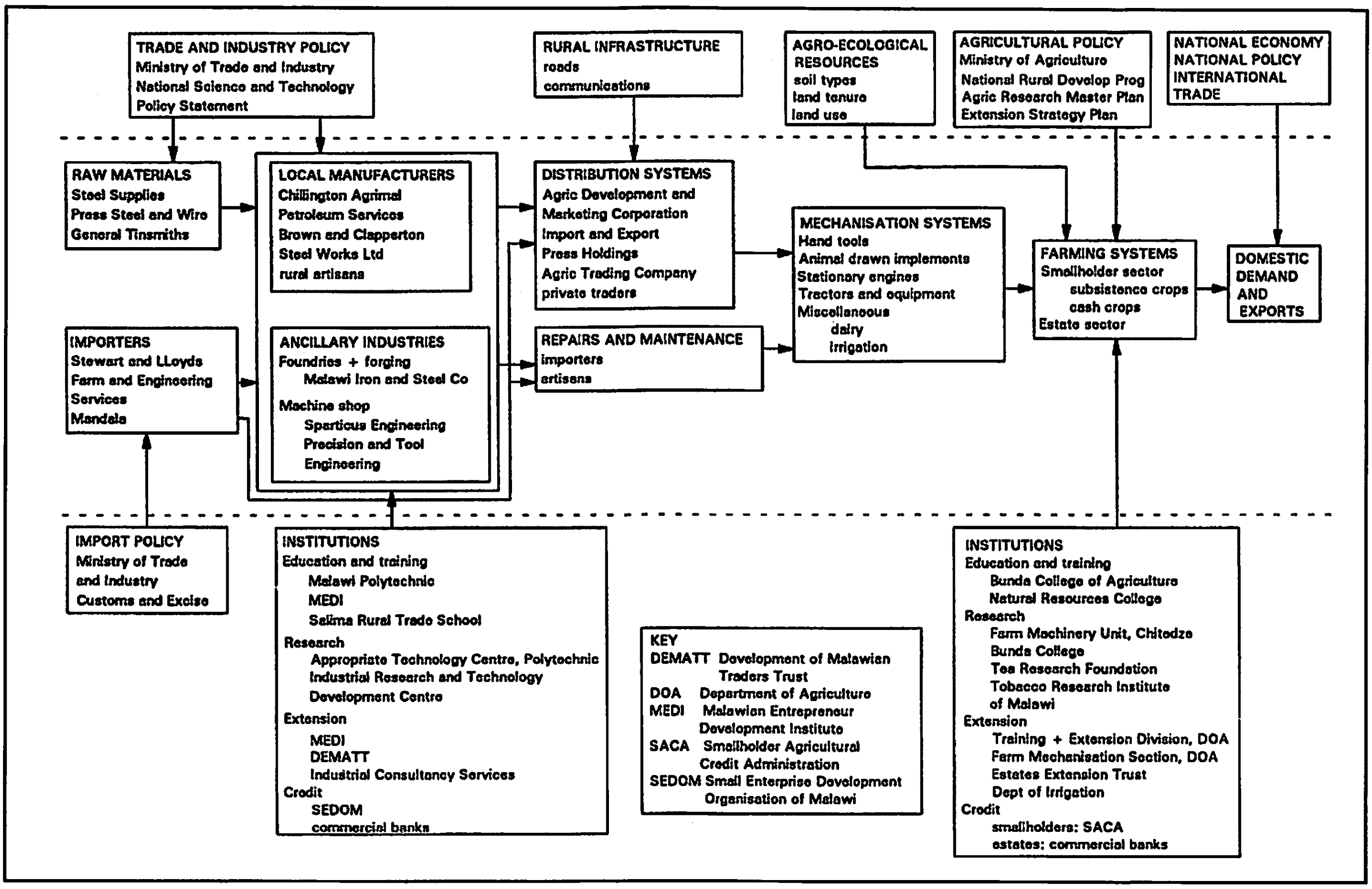

Fig 1. Key components of an Agricultural Mechanisation Systems Diagram for Malawi

Mechanisation is a key input in any farming system. It involves the provision and use of all forms of power sources and mechanical assistance to agriculture, from simple hand tools, to animal draught power and mechanical power.

The potential contribution of mechanisation to agricultural and industrial development is well recognised. With access to appropriate power sources, it is possible to overcome labour constraints and perform critical operations, such as planting and weeding, on time; farming practices may be improved; the area cultivated increased; drudgery minimised; and labour released for other, more productive, tasks.

At the farm level, the benefits are reflected in increased yields or reduced production costs. In addition, the local manufacturing base is developed in order to produce and maintain agricultural tools and equipment.

C Bishop is Lecturer in Agricultural Economics and J Morris is a Reader in Agricultural Economics, both at Silsoe College, Cranfield Institute of Technology.

Missed opportunities: misuse of resources

In practice, however, mechanisation has failed to make its full contribution.

Inappropriate imported technologies may be encouraged by 'gifts' from developed countries or by substantial subsidies. They can over commit scarce skills and foreign exchange to their operation and maintenance, require a comprehensive after sales service, contribute to soil compaction and degradation, discourage the development of locally relevant technology, and ultimately prove unsustainable.

Moreover, the benefits of mechanisation are often shared unequally between types of farmer and between gender.

The contribution of mechanisation to

industrialisation has sometimes been slow, hesitant, and disappointing in terms of income and employment creation. The quantity and quality of locally produced tools and equipment varies, depending on the availability of raw materials and manufacturing skills.

Fragmented approach often to blame

A major reason for the disappointing performance and contribution of agricultural mechanisation to development has been the fragmented approach to mechanisation. This arises from over reliance on unpredictable or unsuitable concessionary aid-in-kind for many mechanisation inputs, and limited co-ordination within and between government and private sector agencies dealing with mechanisation.

Proposals to develop agricultural mechanisation and the local manufacturing base need to be integrated with proposals to develop both the farming and industrial sectors of an economy.

Of particular importance is the need to strengthen or create institutions to improve supporting infrastructure, and to create a policy environment which encourages both private and public sector initiatives.

As sub Saharan Africa faces its most threatening challenge of widespread famine in decades, the overriding commitment must be to secure food production through the effective use of resources. Opportunities cannot be missed, including the effective contribution of mechanisation.

Agricultural mechanisation strategy (AMS) – the action plan

Agricultural mechanisation, in its broadest sense, is thus identified as a sector worthy of development assistance, requiring an integrated and strategic approach to development planning.

A national Agricultural Mechanisation Strategy (AMS) is an action plan which describes in detail how agricultural mechanisation resources will be provided, used and sustained in order to help meet a country's long term development objectives, especially with regard to the agricultural and rural sectors.

The Agricultural Mechanisation Strategy is a component of the national planning process and is formulated within the framework of a country's stated development goals and policies (as set out in a national development plan, for example).

The AMS would typically cover a five year period. It is expected to achieve a beneficial and rational use of agricultural mechanisation technology, and includes:

- an assessment of agricultural mechanisation needs;
- the selection of appropriate technologies;
- proposals on the sourcing of mechanisation inputs;
- the development of local manufacturing capabilities;

and

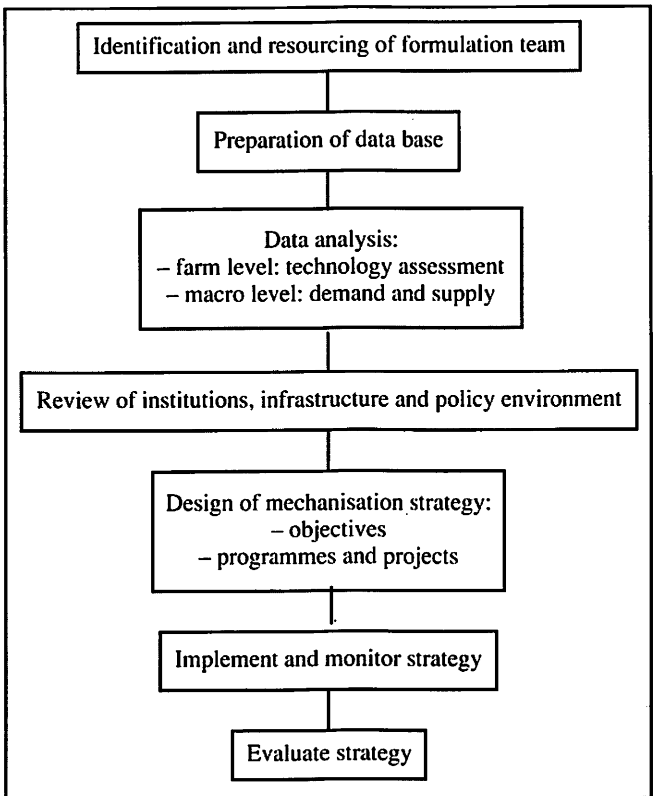

Fig 2. Stages in strategy formulation process.

- improved systems to deliver and maintain the use of mechanisation inputs by farmers.

Malawi – an example of AMS formulation

The breadth of topics during AMS formulation is illustrated in Fig 1. This diagram was prepared during AMS formulation in Malawi conducted in 1991–92.

The systems diagram provides a broad overview of the agricultural mechanisation system in Malawi. The linkages between the demand and supply components for tools and equipment are identified, and set in the context of the external environment.

The **demand side** for mechanisation inputs focuses on the farming systems.

In Malawi, distinction is drawn between the smallholder sector, cultivating customary land, and the estates sector, operating on leasehold or freehold land. Whilst the former is primarily engaged in the production of crops for subsistence and domestic consumption, the latter focuses on the principal export crops (tobacco, tea and sugar).

The farming systems reflect the agro-ecological resource base of the country and agricultural policies. They are also linked to processing and marketing channels, domestic demand, and export opportunities for agricultural products.

The external environment influencing the agricultural sector includes the state of the national economy, national development objectives, supporting institutions, and international trade

The **supply side** for mechanisation inputs traces through the acquisition of raw materials and imports of agricultural tools and equipment, the activities of local commercial manufacturers and artisans, the role of ancillary industries, the distribution system, and repair and maintenance services.

The wider environment addresses policies for imports, trade and industry; rural infrastructure; and supporting institutions.

The diagram in Fig 1 provides the frame-work for data collection during the formul-ation process. Moreover, the systems approach facilitates the identification of bottlenecks and constraints in the system which may be addressed by programmes and projects formulated in the Strategy.

An overview of the key stages in the strategy formulation process is presented in Fig 2.

The formulation team is multidisciplinary, with skills in agricultural engineering, agricultural economics and planning, and manufacturing. The team should be located in an appropriate department, such as the Ministry of Agriculture or the National Planning Office. This team is also likely to be responsible for overseeing the subsequent implementation, monitoring and evaluation of the AMS.

One of the central components of AMS formulation is the preparation of the AMS data base. The latter, prepared using existing information where possible, derives its structure from the systems diagram. The present levels of demand for equipment and machinery by each farming system are estimated, and requirements over a five year period are predicted. Account is taken of the growth in different farming systems, replacement of existing stocks, and the adoption of new or improved mechanisation inputs.

On the supply side, estimates are made of the present levels of output achieved by the local manufacturing and artisanal sector. These are added to the imports of equipment and machinery, in order to calculate total supply. The volume of supply over a five year period is predicted, allowing for changes in the manufacturing sector and imports.

Many factors to be considered

Data analysis and interpretation are conducted at two levels: technology assessment at the farm level; and, at the macro level, an analysis of demand and supply of tools and equipment over a five year period.

Technology assessment involves **technical, financial, economic, social** and **environmental** criteria. Technology change is strongly influenced by political and institutional factors, and this must be recognised. Ministries of both donor and recipient governments are usually favourably disposed to gifts or concessions. Acknowledging that these are likely to continue, technology assessment should screen these arrangements to ensure they are appropriate to the needs and resources of the recipients.

Technical assessment is based on operational suitability, performance, and work rates. Distinction is drawn between systems reliant entirely on hand power, to those making some use of draught animal power (DAP), to extensive use of DAP, and to mechanical power.

The analysis identifies activities in the farming system which are constrained by limited farm power and mechanisation, such as land preparation, the alleviation of which would increase overall productivity and output. However, it is recognised that where farmers currently use traditional, unimproved practices, farm power may not be a constraint.

The adoption of recommended farm practices (such as using improved varieties, appropriate levels of fertiliser application, and greater timeliness and attention to operations) usually requires increased input of farm power.

Thus technology assessment considers both existing and improved management systems.

Financial assessment considers whether a farmer's financial position is improved as a result of further mechanisation. Budgets are compiled for different farming systems and technology combinations, and the additional costs and benefits of using alternative technology packages are identified. The ability of farmers to purchase or hire the mechanisation inputs is also considered.

Economic criteria consider whether the technology is suited to national development objectives and resources. **Social** criteria assess the impacts of technology on the welfare of different groups, and whether particular technologies (eg animal draught) or organisational arrangements (eg machinery sharing) are suited to social and cultural conditions.

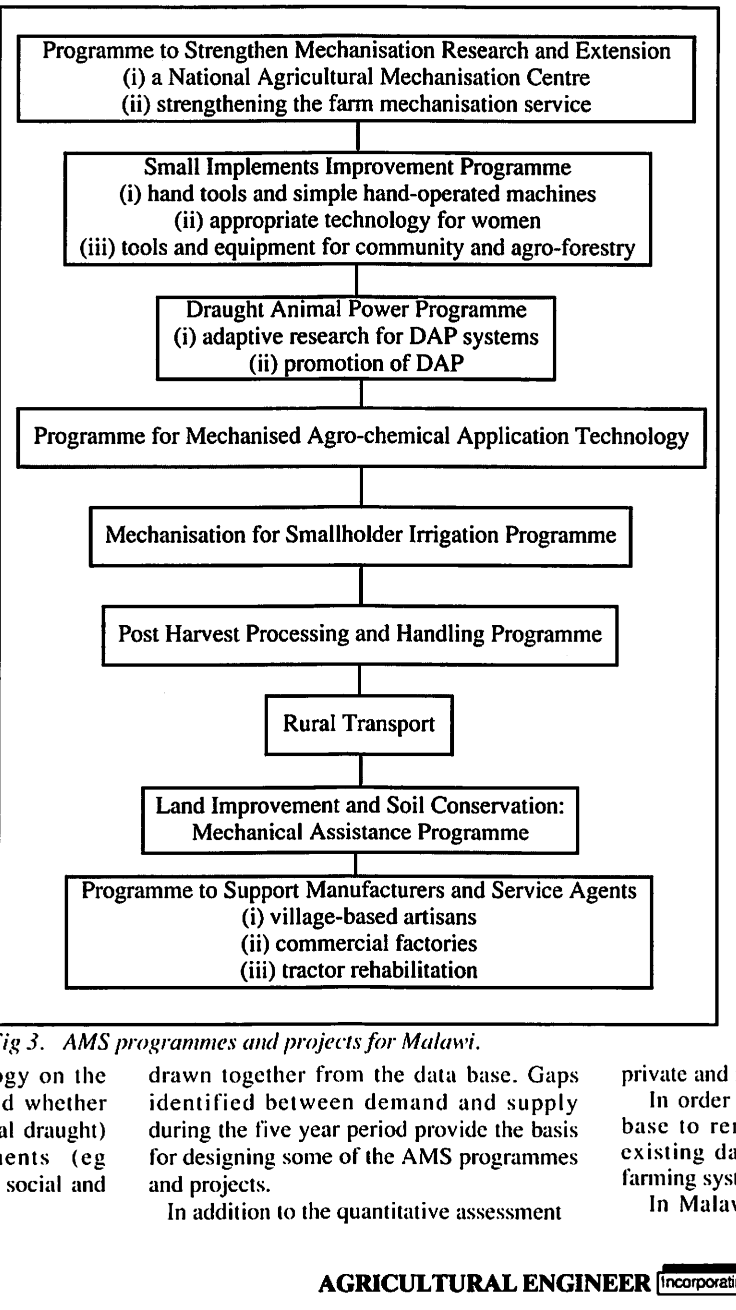

Fig 3. AMS programmes and projects for Malawi.

Environmental criteria consider not only the direct impact on environmental qualities, such as natural ecosystems, but also the environmental stability of the production system itself. For example, the use of mouldboard ploughs on arid, marginal lands, is environmentally damaging.

Identifying the needs

The output of technology assessment is the identification of appropriate technologies suited to local conditions and sustainable over the long term. Some technologies may already be in use in the country; others may be available from elsewhere. Some may require adapting for local uses; others may require initial design and development.

Identifying, procuring, modifying, designing, testing, and promoting appropriate technologies are likely to be important components of AMS design and implementation.

With regard to the demand and supply of agricultural tools and equipment, data are drawn together from the data base. Gaps identified between demand and supply during the five year period provide the basis for designing some of the AMS programmes and projects.

In addition to the quantitative assessment of mechanisation options, it is necessary to consider the policy and institutional arrangements, and infrastructure facilities. If constraints are noted, they may be the focus of an AMS programme or project.

Action plan of programmes and projects

The output of AMS formulation is an action plan of programmes and projects designed to meet development objectives, overcome constraints, and exploit opportunities. Programmes provide an administrative umbrella for co-ordinating individual projects. The latter contain proposals for technical assistance and investment funding. The AMS should be submitted to the standard procedures for appraisal, monitoring and evaluation.

Fig 3 shows the range of programmes and projects identified for Malawi. Some emphasise technology development (eg DAP) whilst others concentrate on institution building and may interface with other sectors (eg rural transport).

High level commitment

Central to a successful formulation process is the interest and commitment of senior government staff, with possible support from the private sector. This commitment underpins the allocation of staff and resources to the formulation team, and facilitates collaboration with relevant institutions during the formulation and implementation process.

To be effective, and to have reasonably easy access to data, staff and institutions, the team must be appropriately located. For example, in Malawi, the team operated through the Ministry of Agriculture's Planning department.

AMS formulation can benefit from technical assistance: this was provided through FAO in Malawi.

The establishment of a local capability in AMS formulation and management is important. This is likely to involve a small national co-ordinating team usually drawn from existing government personnel.

Strong links with the private sector are imperative, especially regarding manufacturing, servicing and distribution. They could be achieved through steering committee with representatives from private and non-governmental organisations.

In order for the preparation of the data base to remain a manageable task, the existing data, particularly regarding the farming systems, must be substantial.

In Malawi, the smallholder sector was

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Electricity generation from wood, straw and wastes

Considerable amounts of public funds have been invested into research relating to the technology and systems of wood biomass and, to a lesser extent straw and waste utilisation for energy projects. Many now believe, says Joe Zygmunt, that the time is ripe for the commercial application of this work, hence the current high level of interest in the possibilities for electricity generation from these materials.

It is important not to underestimate the quantities of fuel required by electricity generation plant.

A hypothetical 1MWe plant would consume of the order of 10,000 *dry* tonnes of wood per annum. At a yield of 10 dry tonnes per hectare of fast-growing coppice this implies a growing area of about 1,000 hectares. Such a scheme would be applicable to large landowners or co-operatives rather than single farmers.

If the technology of gasification (see below) progresses to a fully commercial stage, smaller on-farm generation may become financially viable.

The Non-Fossil Fuel Obligation

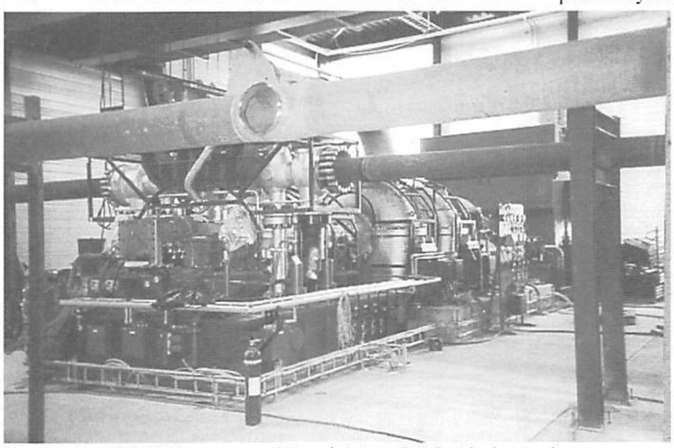
The introduction of the Non-Fossil Fuel Obligation (NFFO) has stimulated great interest in the generation of electricity from renewable sources. NFFO is a system under which the twelve Regional Electricity Companies (REC's) are obliged to source a proportion of their electrical power from fuels other than coal, oil and natural gas. The REC may choose to have its own generating plant, or it may contract a third party to supply electricity to it.

Many find it amazing that a REC might purchase power from a private generator, however the mechanism for this has been in place for some years now. What the NFFO provides for additionally is the payment of a premium price for that electric power produced from non-fossil sources, by means of a levy on sales of electricity to customers.

Joe Zygmunt is a partner in LRZ Bio-Energy Systems, of Buntingford, Herts.

Generating the electricity

On any appreciable scale, electricity is produced in an electrical generator, which is basically an electric motor in reverse, being driven rather than driving. The source of drive depends on the fuel to be used, options to be discussed here are steam turbines and internal combustion engines.



W H Allen 23MW steam turbine driving GEC-Alsthom alternator at Holstebro, Denmark.

The generator unit may either be synchronous, or asynchronous. The former is more common on larger units where the cost of synchronising controls may more easily be borne, and the latter on smaller units. An asynchronous generator is merely an induction motor driven at above its synchronous speed by a prime mover. Such a unit cannot provide standby power, since it is magnetised by reactive current from the public supply, and hence can only be run in

A major advantage of the asynchronous generator is that it requires controls little more sophisticated than a motor of the same size; the synchronous unit on the other hand needs provision to disconnect itself from the public system should that supply fail, lest it remain supplying an isolated network. This would cause major problems on reconnection of the public supply, as the circuit breakers on the fringes of that isolated area would not possess the synchronising equipment necessary to control reclosure.

Power supply to the generator

– IC engines and gasifiers

Internal combustion (IC) engines include petrol, diesel and gas-turbine variants. With the exception of closed-cycle gas-turbines, these engines are incapable of running directly on solid fuels.

However, historically much work has been done on the conversion of solid fuels in to combustible gas which can be fed to internal combustion engines as the sole or part fuel. This gas is produced by means of heating that solid fuel in an oxygen starved atmosphere.

Gasification, as the process is called, has been the subject of a recent resurgence of interest, due in part to its attractiveness for

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adequately covered through the Annual Survey of Agriculture which had been conducted at district level throughout most of the 1980's. Data regarding the estates sector and the manufacturing sector were, however, patchy. Rapid appraisal methods were used to complete the information requirements.

The process of AMS formulation is continual. The AMS data base will require refinements and updating as new data become available. The implementation of programmes and projects will need to be monitored regularly, and evaluated occasionally. Contacts must be maintained between the key institutions and organisations in both the public and private sectors. As a consequence, the AMS may need to be revised to meet changing circumstances.

Systems approach helps identify need for mechanisation

The success of AMS formulation is partly dependent on some strategic planning existing in other sectors in the economy (eg extension, research and development, and credit). The absence of such planning makes AMS a more difficult task.

In conclusion, the impetus and rationale for AMS is dependent on the relevance of farm power and mechanisation as development issues.

Due to the fragmentation of mechanisation interests, awareness of mechanisation problems and opportunities may be limited. Furthermore, farm power may not be a constraint under existing farming systems but may become one as other development initiatives intensify or commercialise agricultural production.

The systems approach to AMS formulation helps confirm the important role of agricultural mechanisation in the development process.

smaller plants, and in part to recent Belgian developments in gasifier design.

Not entirely technically trouble free, gasification awaits full-scale commercialisation, its principal merits over steam plant being lower cost per kW of capacity, and higher efficiencies, in small sizes. For the farmer wishing to grow some hectares of crop and generate electricity on-site, the only current real hope lies in gasification.

– steam cycle plant

For commercial electricity generation, the only current technology choice is via the so-called steam-cycle, hence it will be covered in more detail.

The fuel, be it wood, straw or waste, is burnt in a special combuster with a high degree of efficiency. The heat from this process is used to boil water to produce steam in a boiler. For pressures up to 20 bar, a shell (fire-tube) boiler would normally be used. For higher pressures, a water-tube boiler working at up to 92 bar would be the choice. The higher the initial pressure, the higher the efficiency of electrical generation; and the higher the capital cost. Thus a decision needs to be made as to technology choice, at an early stage.

Dry fuels are normally burnt in a combustion chamber within the boiler heat exchange surfaces, and wet fuels in a refractory chamber, sometimes with preheated undergrate air. Large plant can have efficiencies (net c.v. basis) of up to 90%, especially with economisers and a final stage of heat exchange into space heating water, where applicable.

The steam, which would normally be superheated, is led under pressure to a steam turbine where it expands and cools, turning the turbine to drive the generator. Due to the laws of thermodynamics, an inevitable result of the process is that the steam, having passed through the turbine, still contains a lot of heat energy.

To get the greatest output of electricity from a given amount of steam, the exhaust steam is condensed. This maximises the temperature ratio across the turbine, and hence its second-law efficiency, and also reduces drag on the blades of the low pressure sections of the turbine. However, the inevitable result of condensing is the production of cooling water of up to 80-90°C, which may find a use for space heating purposes. The lower the temperature of this water the more efficient the production of electricity.

In practice, for small plant where no use exists for the waste heat, condensing temperatures of about 45°C would be used.

Exhaust steam may be used directly for process or heating purposes, at pressures of up to 100psi (7 Bar), a *back-pressure turbine* being used in these cases. A result is to compromise the efficiency of electrical generation, compared with a condensing arrangement. If exhaust heat is recovered the resultant installation is called a *Combined Heat and Power* (CHP) plant. In all cases the condensed steam is fed back to the boiler for re-evaporation on a closed loop by the boiler feed pump.

Capital costs of steam cycle generating plant do not vary directly with plant size: there can be significant economies of scale. Depending on fuel cost and whether a use for waste heat can be found, the lowest viable size may range from 500kWe to 5MWe plus. Hence it is essential that a comprehensive feasibility study is undertaken before any such plant is built, as the factors needing consideration vary widely.

Next round of NFFO negotiations should see more schemes based on solid fuels – wood, straw, waste

A brief examination of the published information relating to the Non-Fossil Fuel Obligation indicates that the bulk of the schemes so far accepted are for wind-power and landfill gas, with a lesser number relating to waste (mainly domestic refuse) combustion. It is likely that a fair percentage of these schemes will not proceed further due to finance or planning difficulties.

No schemes are currently operating based on the use of solid agricultural or forestry residues, other than the Fibropower plant in Suffolk using poultry litter. However wood and straw installations are common in Sweden and Denmark respectively, and the technology is proven and available in the UK. Whilst it is true that Danish Government taxation policy favours the use of indigenous biofuels, the situation pertaining in the UK under NFFO is not so far removed.

It is likely that the next round of NFFO negotiations will contain a fair number of electricity generation schemes based on fuels such as wood, straw and other wastes.

Northern Assessors recognise the benefits as an Affiliated Organisation

Affiliated Organisation

The latest addition to the Institution roll of Affiliated Organisations is the Yorkshire based Northern Assessors, an independent practice of Consulting Automobile Engineers, Assessors and Valuers.

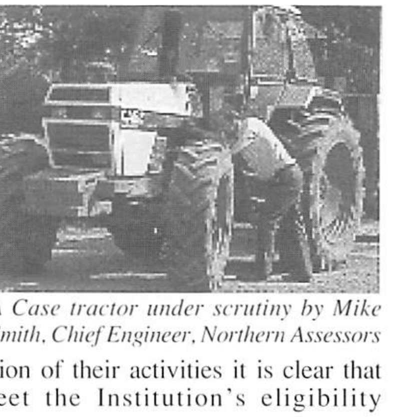
Northern Assessors was set up in 1985 and has seen steady growth. The original staff of three has now expanded to twenty three and today the assessment service on offer is so comprehensive that, along with motor vehicle assessment, the company is able to 'inspect and report on any vehicle from a push bike to a potato harvester'.

Principal, and indeed, founder of Northern Assessors is Gerald Haigh, himself a Corporate Member of our Institution. He it was who saw the potential to his company of applying for I.Agr.E Affiliated Organisation Membership. As he explains, "In our line of work it is vital that we are readily identifiable as offering skilled and competent service. An accident, or other incident, usually demands speedy attention from a qualified Assessor, specialist in the appropriate field". "Being able to use the Institution logo in our letterhead and advertising certainly draws immediate attention to our capabilities in agricultural engineering". "There are also the benefits of considerable discount on advertising rates and the regular promotion through the panel of Affiliated Organisations in each issue of the journal."

Speed of response is at the heart of Northern Assessors steady growth, consider Mr. Haigh. Electronic Data Interchange (EDI) gives virtually instant communication with fellow subscribers whilst, out of the office, PEN PC and BT paging combine to speed up report production. Location close to M1 and M62 motorways contributes to overall speedy response.

Equipment inspection and incident reconstruction.

Besides straight forward vehicle assessment, Northern Assessors can undertake pre-purchase inspections and also post-repair inspections. Additionally, the company is one of the few Consulting Engineers in the UK listed by the Law Society as specialists in the field of Accident Reconstructions. They are also in demand on occasion as expert witnesses in litigation proceedings.



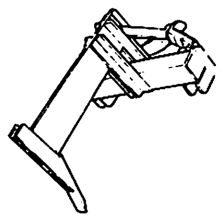
A Case tractor under scrutiny by Mike Smith, Chief Engineer, Northern Assessors

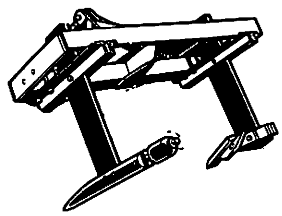
From this brief description of their activities it is clear that Northern Assessors meet the Institution's eligibility requirement as:

'A company or firm engaged in the provision of engineering products or services for use in agriculture, horticulture, food processing, forestry, aquaculture or the amenity industry'.

We are pleased to welcome Northern Assessors as an Affiliated Organisation.

A profile brochure is available on request from Northern Assessors (see facing page for address).





ADVERTISERS INDEX

Electro-optic technology: Instrumentation Tutorials and Exhibition

Eight half-day tutorials, to be held on 27 and 28 January 1993 at Stevenage Leisure Centre, have been organised by Sira Communications Ltd to complement two Exhibitions to be mounted by Trident Exhibitions Ltd on the same two days.

27 January:

- Infrared detectors and cooling devices for surveillance applications
- Engineering applications of fibre optic sensors
- Fibre optic sensors for structural monitoring
- Liquid crystal technology in electro-optics

28 January:

- Optical surface generation to optical tolerances – a review of manufacturing processes
- Broader horizons for machine vision
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- Knowledge based systems in process management

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