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Front linkage designs

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Front cover: Prototype variable slide mounting for inboard ends of front mounted lower links.

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The Institution of Agricultural Engineers

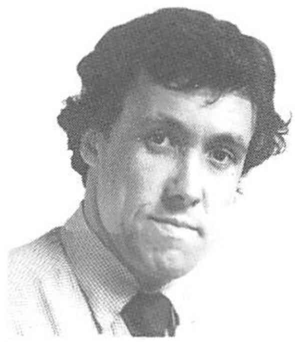
Aspects of tractor front linkage design

P F Hemingway T A Copland

The use of tractor front linkages has increased steadily over the past 10 years in the UK and Western Europe. Early hitches were simple adaptations of rear hitch designs and in their function as machine lifters/carriers performed adequately.

The advent of front mounted tillage equipment subjected these front linkages to forces which quickly showed the adaptation of rear mounted linkage designs to have substantial shortcomings in this situation.

This short paper reviews some design aspects of front mounted hitches and particularly those which have a direct bearing on the tractive performance of the machine to which the linkage is attached.



P F Hemingway

T A Copland

Many of the principles involved in the consideration of front linkages are common to rear linkages, a lucid explanation of which was provided by Inns (1985) in this journal.

The geometry of front linkages is determined by the length of the lower links and top link and the spacial distribution between the attachment points at the implement and tractor ends.

The layout of the implement attachment ends is defined by BS 6818 Part 2 (1987) and for reasons which will become apparent, it is important that linkage and implement designers adhere closely to this standard.

Horizontal converging linkage unsatisfactory for front mounting

Front mounted hitches differ from rear mounted units in that they 'push' the implement and consequently the general sense of direction of the resultant force is from the implement to the tractor.

The converging linkage shown in Fig 1 now used universally in rear applications proves to be unsatisfactory in the front mounted situation.

If the linkage is allowed to rotate as shown, the line of action of the resultant force from implement to tractor is seen to move further and further away from the point of convergence (POC) of the linkage through which all forces transmitted from the linkage to the tractor act. This situation is highly unstable, and results in the implement slewing to one side and staying there.

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Diverging linkage offers greater stability: but lateral controls are still necessary

The diverging linkage shown in Fig 2 is slightly better, in that when the implement rotates the draft force and POC both move in the same direction. It can be seen that the implement will be more likely to be stable if the side force on the implement is large, and it may be that the addition of a soil engaged 'rudder' to the implement will help to assist in lateral stability.

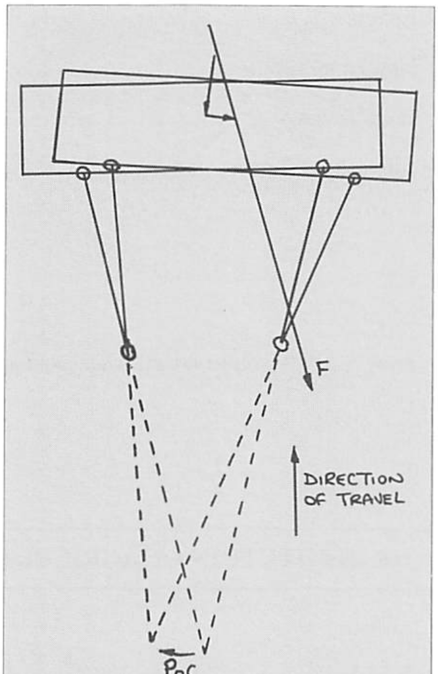

Fig 1. Force direction in horizontal plane on convergent front linkage.

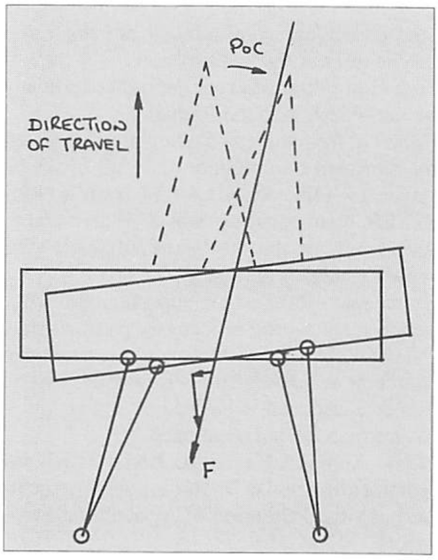

Fig 2. Force direction in horizontal plane on divergent front linkage.

In practice, the front linkage is generally found to be sufficiently unstable that the only workable solution is to lock the lower links either by the use of check chains or by building them into a rigid assembly.

Tensionable check chains may be useful in mounting implements onto the linkage. Rigid linkages must be equipped with quick attach hook type ball ends rather than conventional ball link ends to accommodate implements with cantilevered attachment pins. The hook type ball ends are probably more suitable in this context than on rear linkages. The thrust on them is into the arms rather than onto the hook ends, resulting in reduced problems of splayed hooks.

Locking the linkage laterally can make steering rather difficult, in that if a soil engaging implement is in work it will be unwilling to respond to changes in front wheel steering angle. This problem can be overcome by designing some form of steerability into the implement itself. Generally, this means flexibly mounting the soil engaging part of the implement under a rigid subframe, so that the soil engaging part is 'pulled from the front' rather than 'pushed from the rear'. If the mounting converges towards the front, the soil engaging part of the implement will behave much as if it was mounted on a conventional rear linkage, Fig 3.

Front ploughs – beam realigned to give 'lead to land'

The preceding diagrams refer to centrally mounted implements.

Front mounted ploughs, Fig 4, differ in that the draft force, F, follows a line approximately 5° from the direction of travel. This produces a large turning moment on the tractor which if unresolved would cause substantial problems in steering.

The only way to reduce this effect is to create a larger than normal side force, F_L, on the implement, so that the resultant, F′, tends to act centrally through the tractor rear axle.

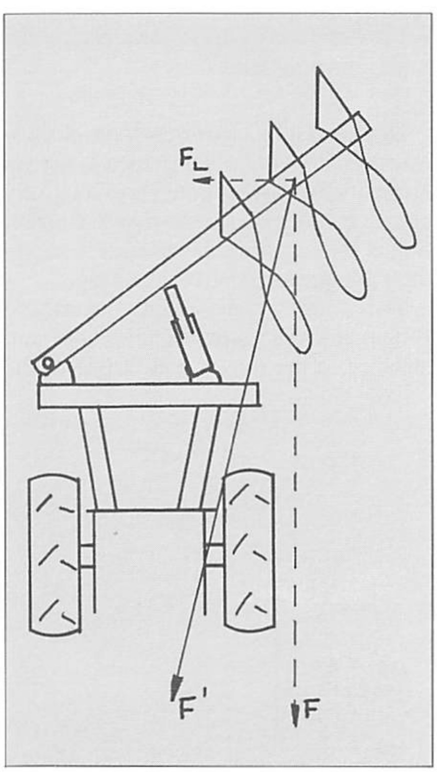

Fig 4. Force direction in horizontal plane on front mounted plough.

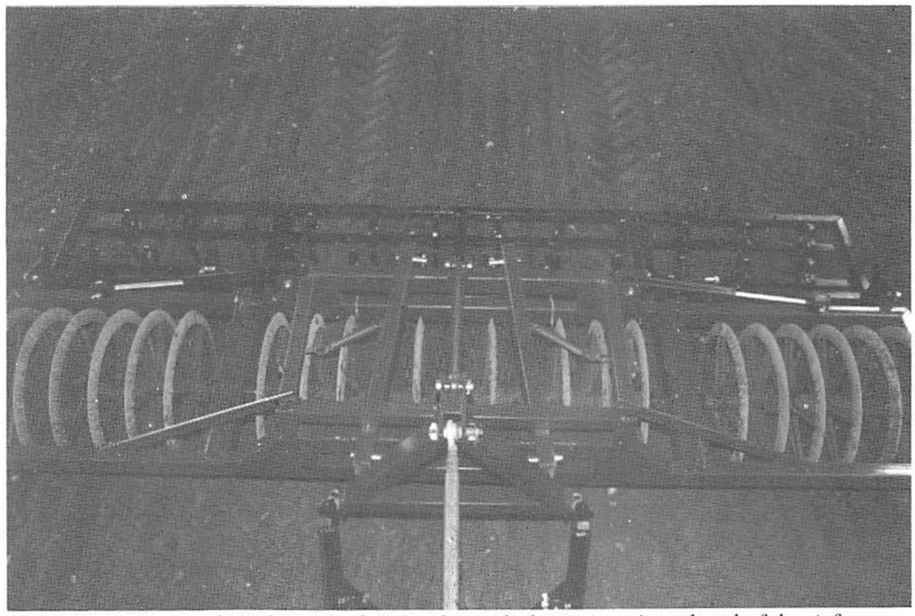

Fig 3. Front mounted implement, showing lower links converging ahead of the A-frame.

In the case of ploughs this can be done by very slightly re-aligning the beam, or the individual bodies to give a 'lead to land' situation. The degree of re-alignment needed is dependant on the size of the plough, the type of mouldboard employed and the dimensions of the tractor to which it is attached.

In practice, such ploughs are made with adjustable angle beams and are set up in the field to give neutral steering characteristics.

Front mounting aimed at better weight distribution for 4-wheel drive tractors

The development of front linkages, particularly for tillage purposes has come about in an attempt to allow lighter four wheel drive (4 WD) assisted tractors to use their power more effectively. These tractors tend to be manufactured for economy reasons as modified two wheel drive (2 WD) machines which have a weight distribution heavily biased to the rear axle. Such tractors, when used with rear mounted implements only, carry substantial quantities of ballast weight over their front axles so as to increase the weight on the driven front wheels.

Vertical plane point of convergence critical for effective weight transfer

The tractor/linkage shown in Fig 5 is a typical configuration where the lines of action through the lower and top links are seen to meet some way above the ground at the vertical longitudinal plane POC. This arrangement is common because it gives relatively good ground clearance to the raised implement and does not reduce the tractor front axle ground clearance. The tractor ends of the linkage members, being rather close together are easily attached to the tractor.

The vector sum, F, of the horizontal and vertical forces on the front mounted free linkage implement will normally act downwards at a fairly shallow angle towards the tractor. The moment of this force about the POC will tend to turn the implement clockwise, deeper and deeper into the ground, Fig 5. For this reason front mounted implements are usually fitted with depth wheels. The support force, N, from the depth wheel will then

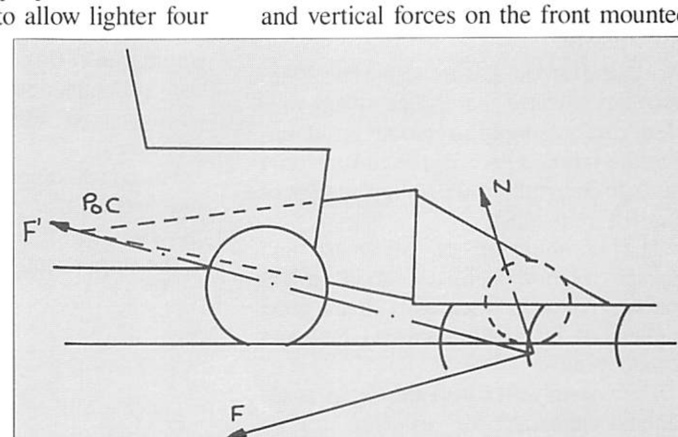

Fig 5. Force direction in vertical plane on front mounted plough.

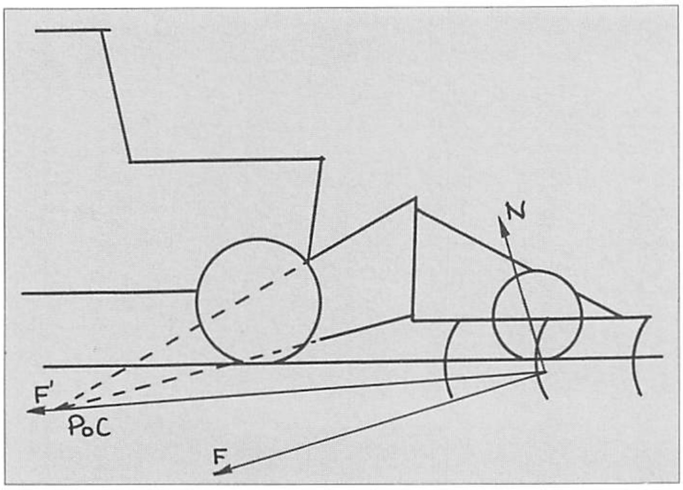

Fig 6. Effect of POC location on weight transferred to the front wheels.

combine with this vector sum such that the new resultant, F′, passes through the POC bringing the combination into equilibrium.

This situation is still not ideal, because the upward direction of the new resultant tends to remove weight from the front wheels of the tractor.

If weight is to be transferred onto the front wheels via the draft force, the POC must be located much lower down as shown in Fig 6. The draft force then produces a clockwise moment about the point of contact of the front wheels with the ground. This geometry has not been widely favoured because of the steep angle of the top link required to place the POC in this position. The angle through which the linkage may be rotated is reduced, which consequently restricts the height to which the implement may be raised.

Top link on vertical slide could be the answer

Work at Harper Adams (Hansen, 1988) has demonstrated that the geometry problem can be simply overcome by mounting the inboard ends of the linkage on a variable slide rather like a short section of fork lift truck mast.

The combination of lift mast and linkage rotation facilitates good weight transfer characteristics as well as good implement lift performance, Fig 7 and front cover.

The system works well although the additional demand for external tractor hydraulic services may limit its success if it were to become commercially available.

Angle of convergence also important

The angle at which the links converge in side elevation has a strong bearing on the lifting/lowering kinematics. If the links are rearward converging (Fig 5), the implement will tend to lift well clear of the ground, but on lowering will touch the ground at the rear first. For a plough this can result in problems of poor soil penetration.

solution which is commercially available uses rearward converging geometry with a hydraulic top link which is extended on lowering so giving 'share first' ground contact and consequently good soil penetration.

Position control – still being developed

Early linkage designs had a rudimentary form of position or height control which by the use of simple chains limited the amount by which the linkage was allowed to drop.

Currently, hydraulic position control is not commonly available on front linkages. The simple hydraulic valves normally used to control front linkages do not lend themselves to being integrated into a control system.

Fig 7. Variable slide mounting for inboard ends of lower front links.

The opposite situation of forward converging links (Fig 8), solves the penetration problem, but gives poor ground clearance on lifting and so is inappropriate.

The usual compromise is to set the top and lower links almost parallel in this elevation, giving a more or less linear lift to the implement. A more sophisticated

However, if linkages were to be electro-hydraulically controlled (which is not yet normally the case) it would be a relatively simple matter to sense the rotational position of the link arms electronically and to use this signal to control the linkage.

The only commercially available system at present uses an adjustable cam attached to the tractor end of one of the

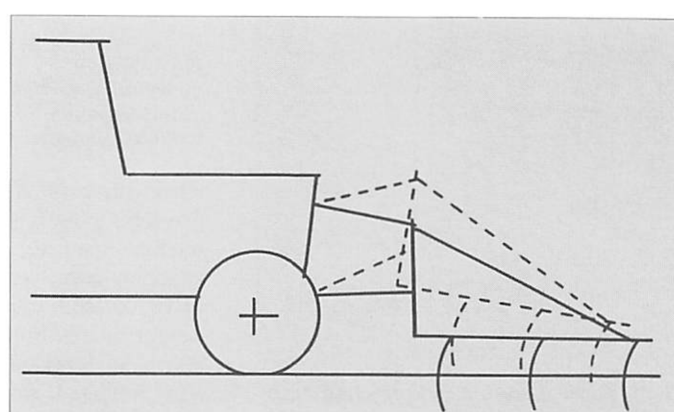

Fig 8. Plough penetration with forward converging links.

lower link arms to set the desired position. A pair of micro-switches sense deviation of the linkage away from this position and provide the necessary corrective signal to an electro-hydraulic control valve.

Draft control – possible through lower links but question if desirable or necessary

For the 4 WD tractor derived from the 2 WD equivalent a logical development of front mounted linkages may be to incorporate a system of draft control in order to maximise weight addition to the front wheels.

For this type of tractor it will be necessary for the linkage geometry to dictate that the resultant draft force from the implement to the tractor has the effect of transferring weight from the back axle to the front.

If it is deemed desirable to develop a system of draft control like that employed on rear linkages, the use of the top link to provide a draft signal is not advisable. In work, front linkage top links are in tension. A lift signal applied to the lower links results in a tipping moment on the implement causing an additional tensile load in the top link. The result is an inherently unstable control system.

There is, however, no reason why the lower links should not be used for draft sensing and it may be that the electronic load sensing pins currently used by several major tractor manufacturers for rear linkage control can offer a suitable source of draft signal.

The upward force imposed on the implement during either the lift or neutral phases of a draft control system operation has the effect of moving the line of action of the force through the lower links downwards towards the tractor. The virtual hitch point (VHP) which is the intersection of this line with the line of action of the top link is seen to move downwards with increasing lift on the linkage from VHPl to VHPs 2 and 3, Fig 9.

As the resultant draft forces Fl, F2 and F3 must, by definition pass through their respective VHPs, the lower the position of the VHP, the greater the clockwise moment the draft force will have about the point of contact of the front wheels with the ground. Consequently a greater proportion of the weight will be transferred onto the tractor front wheels.

The use of a draft control system to suddenly raise a front linkage mounted implement results in substantial weight being transferred onto the front axle and the brackets attaching the linkage to the tractor. It is suggested that for this reason draft control systems should only be contemplated for use with heavily built and attached linkages on tractors with strong front ends.

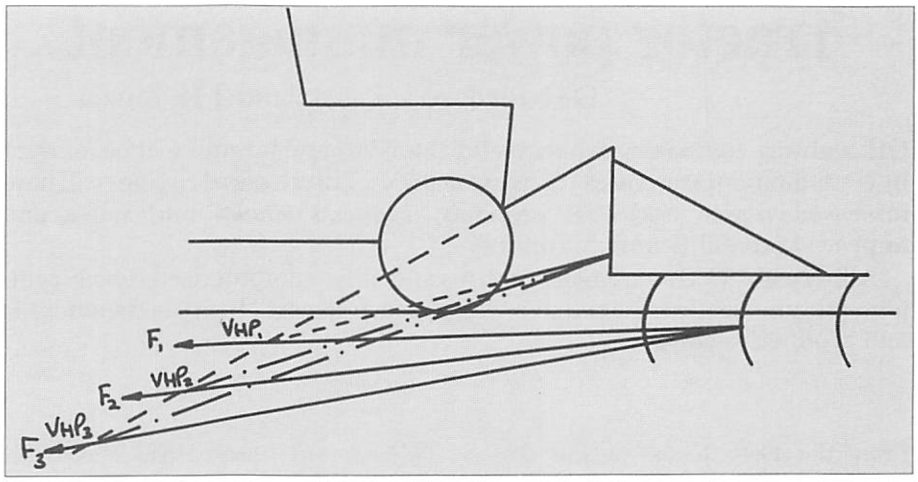

Fig 9. Downward movement of VHP as lift on lower links is increased.

The use of a front linkage draft control system in isolation from a rear linkage system may result in uncontrolled interaction between the two systems causing independent hunting of the two systems. However, if both systems are electronically operated, it should not be difficult to overcome this problem by allocating discrete elements of time for the operation of the two systems.

A modified form of draft control is commercially available which uses the signal from an instrumented front mounted gauge wheel to control an hydraulic top link. This allows improved ground contour following and weight transfer.

Control of dynamic weight transfer for a tractor carrying both rear and front mounted implements is somewhat complex.

The desirability or otherwise of using a draft control system on the front linkage is likely to depend on the configuration of the whole machine. Such factors as the static weight distribution of the tractor and the relative sizes and weights of the front and rear implements need to be taken into account.

Well designed linkage geometry may minimise the potential benefit of a front linkage draft control system.

Avoiding torsional stresses on lateral contours

The rigidity normally built into front linkages means that problems may be encountered with wide implements in their attempts to follow lateral ground contours. Large torsional stresses may be imposed on the linkage and attachment brackets.

Such implements may benefit from the use of a headstock which allows some pivoting action along a fore-aft horizontal axis. A commercially available mechanism of this type employs two hydraulic rams to control the degree of implement rotation and has proven workable with implements up to six metres in width.

Conclusion

The market place has now firmly accepted the concept of four wheel drive as the more efficient way of developing drawbar power in many situations. The desire to maximise the output of four wheel drive tractors will demand increased use of front mounted linkages and implements.

The operational characteristics of such linkages require careful design of both the linkages themselves and the implements which are mounted on them if problems are to be minimised.

Currently few manufacturers offer systems enabling control of such equipment. As expertise in the use of such equipment grows and demand increases, better implement/tractor performance and control will be demanded. Such systems are likely to take account of the 'whole machine', that is the tractor with both front and rear linkages and implements.

The potential for the development of a completely standard system is limited due to the wide variation in tractor configuration and implement types.

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Tractor power management

D H Jordan, L I Ross and J H Tanzer

Off-highway engine developments for the 1990s and beyond will be marked by continuous improvements of many features. Future diesel engines will have improved power and fuel economy, reduced smoke and noise and improved reliability and durability.

Allied with electronic engine controls and other computerised vehicle components, automatic transmission will give overall cost effective, dependable and productive power units.

From the 1950s to the present time, engine developments for agricultural and off-highway applications have been marked by slow and steady improvement in fuel economy, power rating, durability, reduction of smoke and noise.

In the late 60s and early 70s turbocharged engines were somewhat distrusted but soon gained favourable acceptance. Aftercooling was soon added as the next step in improving performance.

For the 1990s and beyond, various improvements in these and other features are likely to accelerate as major manufacturers focus their attention on customer driven quality, competitive pressures and cost-effectiveness. Also, off-highway engines will benefit from technological advances that are necessary to meet stringent emission standards applicable to on-highway engines.

Future trends include re-entrant combustion bowls, electronic fuel injection systems with high pressure capability and rate shaping, and reduced friction.

Power and fuel economy

Details of many of the engines currently produced by major manufacturers are given in the results of a survey recently conducted by a leading engine consultant (Ricardo, 1988). Engines in the survey fall within the following parameters:

Combustion system:	Direct injection
Bore size:	95–115mm
Stroke/bore ratio:	1.0–1.2
No. of cylinders:	3,4 or 6–in line
Swept volume:	0.85–1.1 per cyl
Rated speed	2200–2500 rpm

Power ratings of most engines are dependent on the type of aspiration and number of cylinders. The full load rated speed, brake mean effective pressure (BMEP) for current production engines varies from 7 bar for 3 cylinder naturally aspirated (NA) engines to 14.3 bar for 6 cylinder turbocharged and aftercooled (TCA) engines.

Minimum full load fuel consumption for agricultural engines in the 30–150kW range is expected to be about 210g/kW/h for NA engines and 200g/kW/h for a TCA engine. An example of a higher rating is a 7.6 l 200kW engine with air-to-air aftercooling which has a rating of 17.5 bar and a minimum full load fuel economy of 190g/kW/h (Whiting *et al*, 1988). Another example of a highly rated NA engine is a 3 cylinder, 3.3 l headland* rising piston rated at 8.5 bar (McLean *et al*, 1986).

*The first piston ring located at the top of the piston.

Since these engines do not have to meet any stringent emission laws except noise and smoke limitations, there is great freedom in selecting optimum timing for fuel economy consistent with the appropriate upper limit on maximum firing pressure to maintain structural durability. Fig 1 shows minimum full load brake specific fuel consumption (BSFC) for off- and on-highway medium duty diesel engines respectively (Ricardo, 1987).

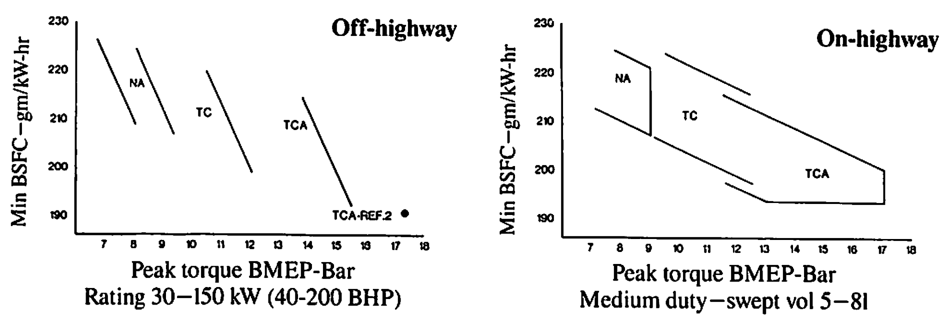

Fig 1. Minimum full load BSFC for off- and on-highway diesel engines

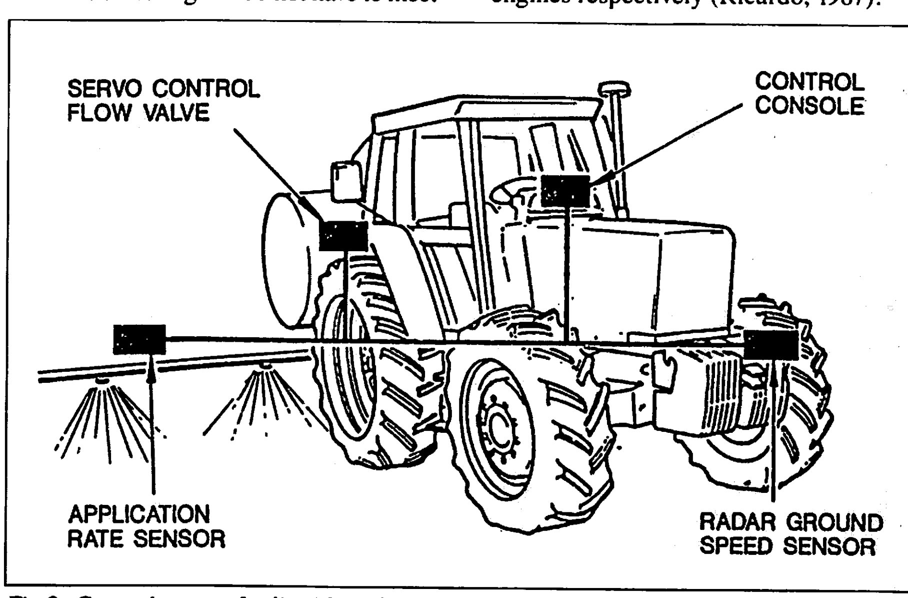

Fig 2. Control system for liquid application rate based on true ground speed *(see p109)*

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Focus on

further papers from

As already reported, the 1989 Annual Convention included two parallel afternoon sessions. These were both devoted to matters of quality–of quality in agricultural production and of quality in the agricultural engineering industry which supports it.

As a follow on to the main sessions, members attending the Convention had opportunity also to participate at one of the evening meetings organised by Specialist Groups of the Institution.

Quality

the Annual Convention

In our last issue we have already covered the session on Product Quality. Here, we now present the papers from the equally important parallel session – "Design Quality" – chaired by Council Member, Brian Finney, ADAS.

In this issue we also report one of the Specialist Group meetings – the inaugural meeting of the new Forest Engineering Specialist Group – where Roger Hay spoke on the subject 'Specifying forestry machinery'.

Engine features for improved performance

Significant features which may improve economy include:

- Combustion system optimization
- Reduced dead volume
- Reduced engine friction
- Reduced pumping work
- Increased power rating with appropriate turbocharging and aftercooling

Combustion system optimization trends include using swirl ports in place of directed ports and re-entrant combustion

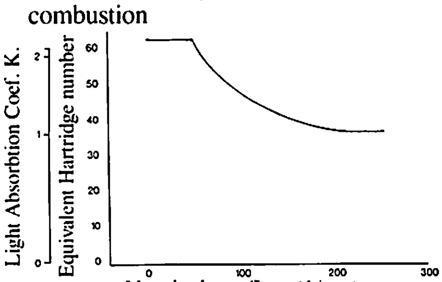

Fig 3. Diesel engine exhaust smoke limits. (European emission regulation)

bowls for better fuel air mixing and more complete combustion. Reducing the dead volume contributes to more effective air utilization. Four ring pistons are being replaced with three ring designs; better piston skirt conformability and expansion control characteristics are being introduced to reduce friction and noise. Larger valves and higher lift camshafts reduce pumping work and improve efficiency. Increased power ratings by turbocharging and aftercooling are being used to improve efficiency.

Torque back-up will continue to be an important feature of agricultural engine development as it affects the lugging performance of the vehicle. Injection pump modifications as well as electronic control of fuel injection equipment will allow optimum torque curve shaping for a given application.

Smoke and noise limitation

The only exhaust emission legislation relating to agricultural vehicles is an EEC directive 77/537/EEC under which smoke limits are at a given load and speed as shown in Fig 3.

In practice, smoke levels at full load are likely to be limited by marketing considerations and competitive position. Smoke outputs for given air/fuel ratios for current, well developed diesel engines are shown in Fig 4.

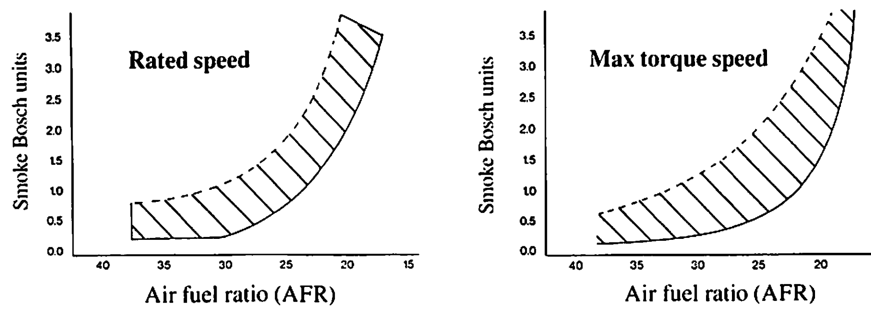

Fig 4. Smoke vs air fuel ratio comparison at rated speed and max torque speed. (DI NA engines c.1 litre/cyl.) Band of contemporary engines

Further reductions in smoke emission may be feasible by adopting higher pressure fuel injection equipment, smaller injector nozzle hole sizes, and decreased injection duration, as has been demonstrated on heavy duty diesel engines and is shown in Fig 5.

Improvements in noise levels (dBA) and quality of sound are driven primarily by customer acceptance rather than by any legislated standards. It is suggested that modern, naturally aspirated engines are, on average, 2 dBA quieter than they were 20 years ago and future engines will be quieter still based on advanced techniques for structural optimization, more precise control of fuel injection systems such as fuel injection rate shaping to reduce ignition delay, close fitting pistons and proper attention to radiating surfaces such as sump, timing cover, valve rocker covers.

Engine type–Volvo TD120F
Fuel injection equipment specification.

	Standard	*Rematched*
Fuel pump type	Bosch P3000	Bosch P7100
Static pump timing	23 BTDC	24 BTDC
Plunger dia (mm)	12.0	13.0
Cam lift (mm)	11.0	12.0
Pre-lift (mm)	2.4	2.5
Cam plate (mean) (ms/deg)	0.35	0.39
Nom. injection rate (mm/deg crank litre)	10.03	12.91
Nozzle hole dia (mm)	0.36	0.34

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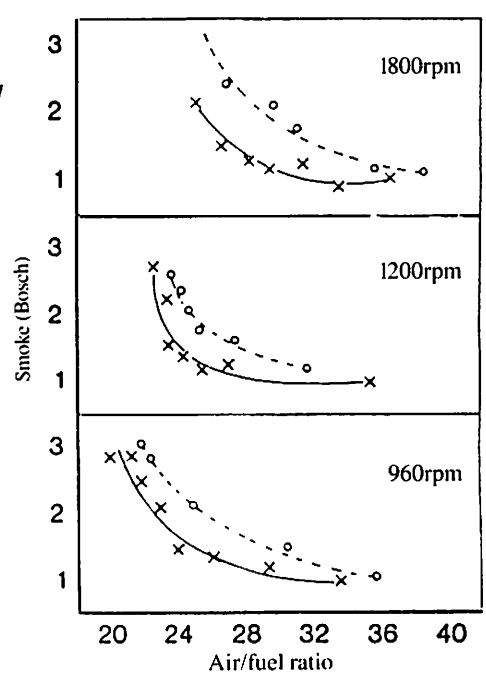

Fig 5. Effect of fuel injection equipment vs air/fuel ratio.

Reliability and durability

Table 1 shows the required reliability and durability for typical medium duty turbocharged diesel engines (Ricardo, 1988). A 50% improvement in durability for future engines is expected as customers demand increased 'up-time' for their vehicles to reduce the cost of maintenance and repair.

Automatic transmission design

Before moving to consideration of Automatic Transmission Design and the other related topics of this paper it is

Table 1. Reliability and durability

	Severe applications	*Less severe applications*
Period by which 10% of engines will require rebuild–B10 Life	161000 km 4000 hours	380000 km 9400 hours
Period by which 50% of engines will require rebuild–B50 Life	241000 km 6000 hours	550000 km 13700 hours
Projected future B10	241000 km 6000 hours	550000 km 13700 hours
Projected future B50	322000 km 8000 hours	750000 km 18600 hours

Reliability (probability of survival for first 100000 km) –critical failures 0.90
–all failures 0.55

appropriate to identify where we are in transmission application today. Table 2 shows that situation by powerclass and range.

'Automated Powershift Transmissions' can and will outperform conventional powershift transmissions in most operational modes. However it is a sophisticated system and many potential users are, and will be, afraid to purchase anything they do not undersand and/or cannot repair.

Table 2. Transmission applications today

Feature	*30–53 kW*	*53–90 kW*	*90 kW upwards*
Torque multiplier	limited use	frequent use	some use
Partial power shift		covering 3 or 4 gears –in increasing use	significant use
Full powershift		rare	use increasing

Automatic transmissions for off-highway vehicles are in many ways similar to the popular full powershift transmission. The major differences are the automated, pre-programmed control features.

The basic automatic transmission designed for tractors consists of most of the components used in a multi-speed powershift transmission, plus a sophisticated, micro-processor based control system.

Electro-hydraulic components, such as solenoid operated hydraulics and/or electronic pulse width modulated control valves, are used to activate the hydraulic clutches.

The pre-programmed transmission shift sequence and/or response to changing wheel torque requirements generally also can be optimized to result in improved fuel economy and/or increased work output.

The added capability of improving gear shift smoothness and tractor starting, (eg inching performance) due to electronics, is another advantage. Intelligent design and use of the transmission shift algorithm, speed and pressure sensors, software, hardware and interfaces are, however, vitally important to proper performance.

Self diagnostics and repair monitoring: absolute necessity

In general, most properly designed

For this reason, Self-diagnostics built into the electronic controls are an absolute necessity.

A properly designed automatic transmission should be equipped with a microprocessor with self-diagnostic features, such that the microprocessor can aid in identifying a problem and provide trouble shooting instructions. Most importantly, however, the self-diagnostic capability should provide warning signals to avoid serious component damage or safety hazards.

As an example, an electronic feature option, which should promote customer acceptance of electronically controlled equipment, would be a Diagnostic Repair and Warranty Monitor;

Such a type of monitor would be programmed to check appropriate parameters and components on the transmission, engine etc, and 'walk' the mechanic through a trouble-shooting flow chart. Automated tests could then verify the proper installation of replacement components such as sensors, electronic modules, etc. In addition, a non-volatile memory would record the occurrence of intermittent problems and provide warranty information.

The non-volatile memory can also store a signature profile of important performance data taken during the final acceptance test of an engine or transmission, etc, prior to the initial service date. To evaluate warranty claims for major components such as transmissions or engines within a vehicle, important warranty data such as service hours, component overload parameters, etc, could be permanently stored and then checked for possible abuse.

This type of diagnostic option could be incorporated in most electronic control systems for little extra cost, yet would make the potential buyer and manufacturer less reluctant to use a new state of the art technology.

Integrated power train controls for tractors – within 7-10 years

Automatic transmissions for off-highway vehicles are steadily growing in numbers and, when integrated with other computerized vehicle components, such as electronic engine controls, can be produced to be cost effective, dependable and last but not least, more productive in use.

In terms of interactive vehicle control there is a great deal of experimental and development work in progress. Some has been presented to our Institution.

Bellanger (1987) gave details of wheel slip control within his paper on tractor hydraulics and implement control and Sims *et al* (1988) referred to tractor efficiency and fuel conservation as examined in New Zealand. Other examples include Grogan *et al* (1987) who explored tractor performance monitoring and optimisation using a system which advised the driver when to select the optimum gear and engine speed, and Jahns and Speckmann (1988) who gave a broad survey of actual and potential driver aids and needs.

The patent field also holds out its promise to powertrain control system development. In an earlier paper on power utilisation in tractors, Jordan (1988) suggested that it would be feasible to provide powertrain interactive controls to the farmer within 7-10 years.

Interfacing problems

As their name describes **powertrain interactive controls** are integrated controls of the complete powertrain, ie, a combination of electronic engine, transmission and drive axle controls.

The advantages for off-highway, industrial and farm tractors have long been recognised when combining centralised, microcomputer based controls with hydraulic activating devices.

The interfacing problems between microcomputers, actuators and sensors

Table 3. Future automotive control opportunities

Sub system	*Limiting Factor*			*Technology Needs*				*Relative technological difficulty*	*Estim intro date*	*Major development needs*
	Cost	*Technology*	*Concept*	*Sensors*	*Actuators*	*Displays*	*Electronics*			
Wheel lock control	•							small	1987	none
Steering control	•	•		•	•			large	1992	power mosfets
Automatic brakes	•	•		•	•			large	1995	microwave transceiver
Collision warning	•			•				medium	1990	microwave transceiver
Vehicle weight	•			•				low	1988	load sensor
Axle load	•			•				low	1988	load sensor
Air deflector control	•			•	•			low	1989	load sensor
Tyre pressure	•	•	•	•				medium	1989	pressure sensor
Vehicle location	•	•	•	•				medium	1993	concept
Navigation	•	•	•	•		•		medium	1993	concept
Security alarm	•	•	•	•	•			large	1990	concept
Road condition monitor	•	•	•	•				large	1995	concept
Refrigeration monitor	•			•				low	1988	none
Crash recorder	•	•		•				medium	1990	accelerometer
TRP recorder	•	•	•				•	medium	1990	card memory

however, continues to slow down the programmes on economical, interactive control applications. Not only must these peripheral control components be economical and dependable, but they must also be dynamically compatible with the application and with the computerised system. System response and stability is dependent on their inter-relationship.

Table 3, recently published by an electronic control magazine relating primarily to automotive needs and applications, indicates engineering development needs, cost reduction efforts and major concerns, applicable also to the powertrain control systems for the off-highway vehicle industry.

Although cost effectiveness certainly applies to the off-highway industry as well, certain restrictions such as limited installation space and weight do not apply to the same degree as in the aircraft and automotive industries. The latter developments provide for reduced design and application concerns in our industry.

When comparing actual cost to benefit considerations in the off-highway industry, powertrain interactive controls, using state of the art electronic components, are definitely a major resource to improve tractor operating costs, work output, operator convenience and cost effectiveness.

The key issue on most successful applications is the degree to which the design allows for complete, integrated control system applications. The latter generally affects cost, performance and reliability. A typical example would be the use of one common sensor for engine controls, such as speed (rev/min) sensor, and use its signal wherever needed within the complete powertrain system. The benefits are not only in the elimination of the cost for Additional sensors – fewer parts also provide for fewer parts which can fail, and last but not least, the computational load requirements within the microprocessor, such as algorithm/software strategy, generally results in additional advantages.

The following are a number of vehicle or powertrain controls which should be considered when designing a new interactive powertrain control system:

- Engine management
- Transmission gear shift
- Engine-transmission temperature
- Vehicle traction
- Torque load sensing
- PTO
- Brakes
- Differential lock
- Hydraulics
- Operator warning controls for powertrain protection
- Diagnostic, troubleshooting monitor.

As an encouragement to the designers and planners of control systems it should be said that there are several cost effective, integrated powertrain control systems within our off-highway industry in service. This proves that it is certainly not impossible to utilise integrated electronics cost effectively, while obtaining additional operational feature benefits.

Reducing wheel slip

The need for improving tractor tractive efficiency, ie, to reduce wheel slip is well known. Controlling wheel slip is, however, a very difficult task for any tractor operator without appropriate equipment.

The most useful control system available for this purpose is a microprocessor based radar ground speed sensing unit and its monitor. A typical installation of a radar ground speed sensing unit is illustrated in Fig 2 on page 106.

An alternative system is a radar velocity sensor. This works on the principle of generating a signal whose frequency is proportional to the true vehicle ground speed. This signal is then used by additional electronic components to provide the tractor operator with a monitor type display of information, such as speed, distance travelled, area covered, tractor wheel slip etc.

Fig 6 shows the major components of a Radar Velocity Sensor. The sensor operates by directing a beam of microwave

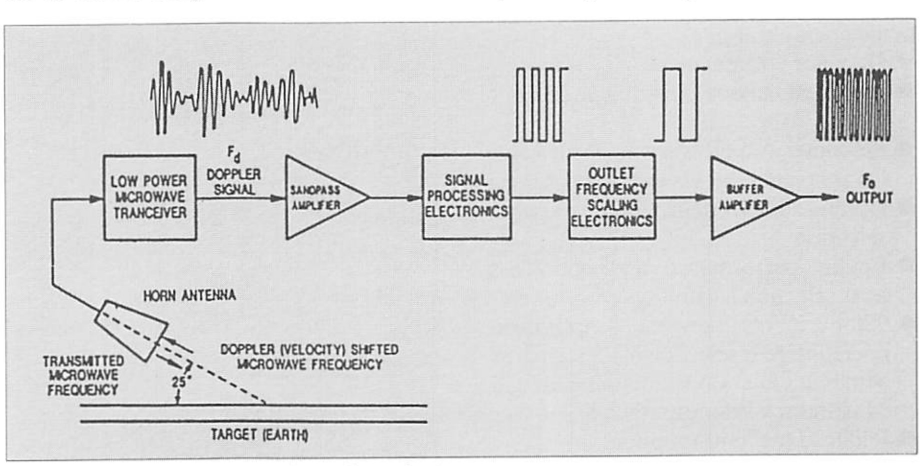

Fig 6. Major components of a radar velocity sensor.

energy at the ground. The frequency of the energy reflected back from the ground is then compared with the freqency of the transmitted energy. The difference between the transmitted and received (reflected) frequencies is proportional to the vehicle speed.

The doppler frequency shift 'F_d' is given by the following equation:

$$F_d = 2\,V_g/\lambda \cos\phi$$

where:

V_g is the magnitude of the velocity vector (44.7 cm/sec=1 mph).

λ is the wavelength of the transmitted signal (1.243 cm for 24.125 GHz).

ϕ is the angle between the velocity vector and the centre of the antenna beam (nominally 35°).

The fractional multiplication, fm, required to produce the Dj Radar I standard output 8 Hz/km/h (44.7 Hz/mph) is f_m=.758.

The microprocessor system amplifies and evaluates each cycle of the doppler frequency signal in a complex software algorithm and then generates and displays the essential information at the display monitor. Additional software, containing efficiency computation capability, will help the operator to optimise vehicle tractive efficiency.

Automated gear selection

In both the automotive and off-highway industry, many automated transmissions, utilising microprocessor based transmission gear have been developed successfully due to a major continuing effort reported by all major manufacturers.

Microprocessor based gear selection systems can be designed with features which are very difficult or impossible to match with conventional gear shifting devices. High speed responsiveness and relatively unlimited capability to store optimised operating and performance monitoring instructions in the microcomputer are the main opportunities.

The most popular features and benefits to the operator are:

- Operator convenience
- Improved, smoother shift feel, ie, shift quality
- Smoother vehicle starting at different loads in different starting gear positions
- Optimised shift point timing and gear selection
- Engine performance and optimised gear selection capability
- Choice of several optimised operating/gear selection modes, such as Minimum Fuel Consumption/Cost and Maximum Work output mode
- Reduced fuel consumption
- Improved work output
- Visual performance monitor to assist the operator to make optimised gear shift selections with manual transmissions.

A microprocessor based Transmission Gear Selection System generally consists of:

- Conventional mechanical and hydraulic gear shift components, such as, powershift clutches, etc
- The shift control lever and/or the keyboard shift mode and input device
- Electro-hydraulic shift activators
- Electro-hydraulic or pulse width modulated gear selection and shift valves
- Sensors for speed (rev/min), torque, pressure and timing
- Peripheral interface components
- Microcomputer with its analog to digital and digital to analog converters, microprocessor, EPROM, RAM
- The electrical system consisting of voltage regulator, transducer drivers, transducer electronics and the microcomputer.

Operation of a typical gear selection/shift control system:

The intelligence of the control system is in the computer software. The software structure can be described as modular with a major data format and interrupt processing relationship with the main program flow. Numerical values can be defined in a table format, such that the software is portable and can be used for various transmission models. There are three functional types within the system modules:

- Sequential processors:
  The programs contained are designed to take care of the main processing to monitor and control the system
- Subroutines:
  The subroutine programs perform supportive utility functions and can be initiated from one or more locations within the main program flow.
- Interrupt routines:
  These programs always obtain control from an interrupt source, such as:
  −engine/transmission speed
  −analog to digital conversion
  These interrupt programs always return control to the point of interruption.

A typical flow chart is shown in Fig 7.

In conclusion, it should be said that the microprocessor based gear shift selection aids are a much needed transmission control option, which not only add to the operator comfort features, but also can reduce tractor operating cost and improve work output. It is expected that this option will become increasingly available in the years to come.

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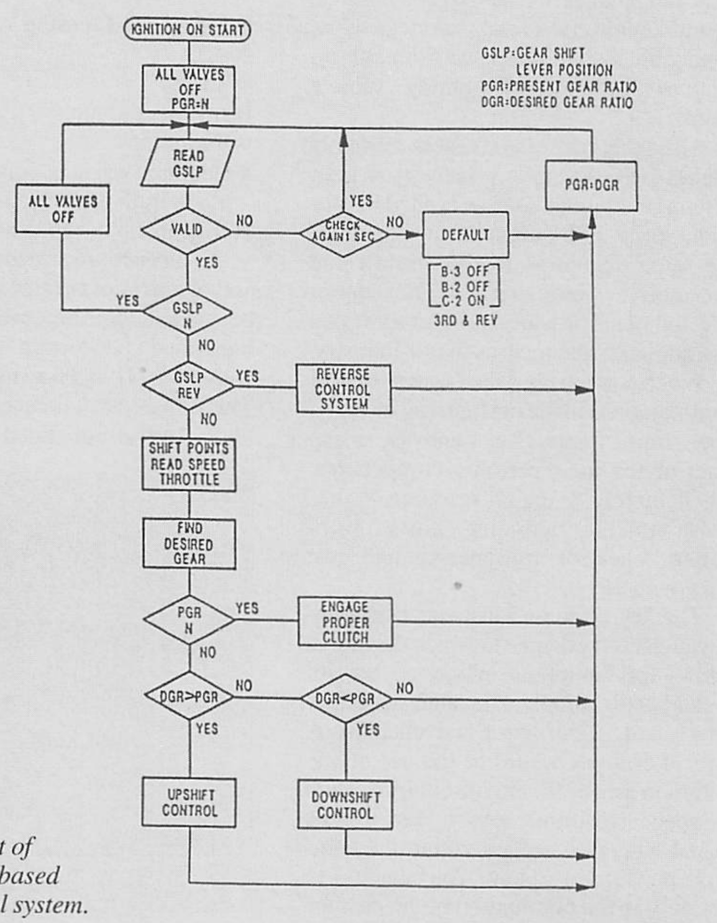

Fig 7. Flow chart of microprocessor based gear shift control system.

Intelligent suspensions

D A Crolla

The topic which has dominated vehicle dynamic studies over recent years is that of suspension systems. These are variously described as 'active', 'intelligent', 'adaptive', etc.

Public attention has been drawn to these developments through the glamour of Formula 1 racing, although ironically, advanced suspensions offer greater potential for much more mundane vehicles.

The technology behind the various types of advanced suspensions is not, however, well understood, with much of the literature containing dramatic comments and ambitious claims for the potential improvements in performance.

The first aim of this paper is to describe the alternative systems that have been proposed. The second is to address two fundamental questions:

- **What are the potential benefits offered by these alternative systems?**
- **What are the practical implications in terms of costs and power requirements?**

The final aim is to tailor the above comments to off-road vehicle design. Work to date (Sharp and Crolla, 1987) has concentrated on road vehicles, mainly passenger cars, and some additional interpretation is required before existing measured and predicted results can be applied to off-road conditions.

To set the scene some comments on current practice in passive suspension design are appropriate. The fundamentals of the suspension problem are reasonably well understood and good design requires an effective compromise between:

- passenger (and cargo) ride comfort
- suspension working space usage
- tyre/ground contact force variation
- vehicle attitude control.

The quarter car model, shown in Fig 1, provides a good framework for considering the first of these key aspects of performance (Sharp and Crolla, 1987). For example, designers recognise that low spring stiffnesses and hence low natural frequencies lead to good isolation, but such suspensions then require large dynamic deflections, and conflict, therefore, with other demands on space. Selection of damper settings, often the subject of an immense amount of practical testing, is a compromise between ride vibration isolation and control of wheel hop resonance.

Choice of the best suspensions settings would be difficult enough if the problem were really as simple as implied in Fig 1, but the real vehicle has a wheel at each corner and it relies on the suspension to control body roll when cornering. Roll behaviour is of key importance in dictating the handling behaviour of the vehicle and, in general, a soft suspension which provides good isolation also allows significant body roll which is undesirable for good handling and stability. Hence, yet another set of design compromises must be reached. Although a somewhat over-simplified view, this arrangement is weighted towards handling (stiff suspensions) for most European cars and towards ride (soft suspensions) for American and some French cars.

The potential for an intelligent suspension which can do better in relation to this compromise is now clear, but there is one more important issue.

Real vehicles operate over a wide range of running conditions (ie, surfaces and speeds). If one were simply able to pick the passive spring and damper settings for each condition, then significant performance improvements could be gained without the need for any of the expensive actuators that are often associated with intelligent or active suspensions. This principle that the suspension **adapts** to the particular running condition, offers another potential source of improvement and discussion of it will form an important part of this paper.

For off-road vehicles, there are some additional constraints to be considered (Crolla *et al*, 1987).

First, the range of surfaces over which an off-road vehicle must operate is normally much wider than for a road vehicle.

Second, for agricultural applications, the vehicle may have an implement attached which requires accurate control relative

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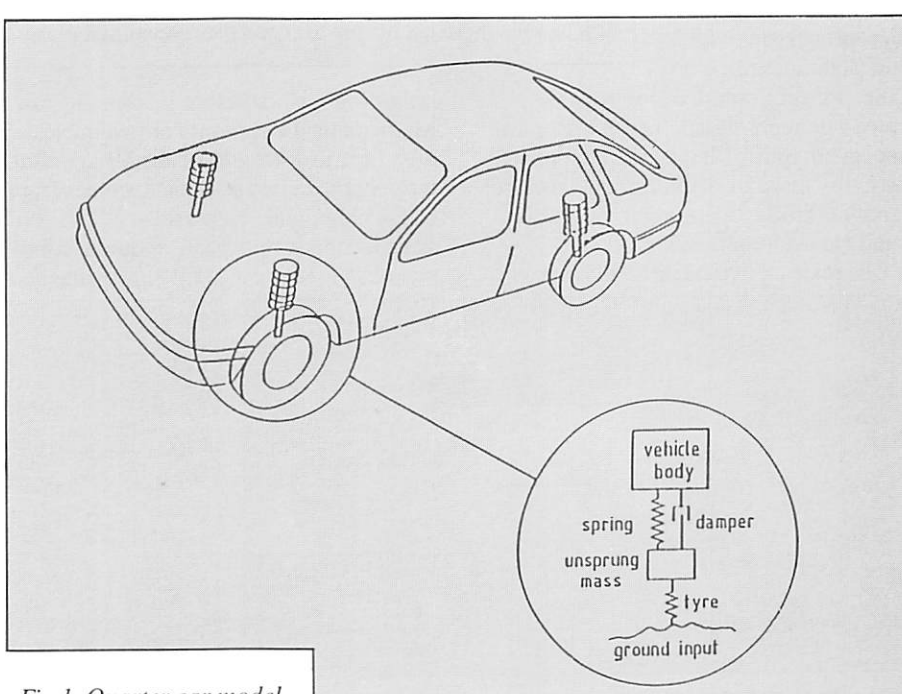

Fig 1. Quarter car model.

to the ground surface (eg, plough, sprayer boom).

Third, the constraints imposed by the requirements for all wheel drive and high transmitted torques further restrict the design freedoms for advanced suspensions.

Finally, although controlling the dynamic tyre/ground load remains an important feature in maintaining good on-road handling, it is also important off the road for controlling the generation of tractive forces.

Suspension systems defined

Passive – A system comprising only springs and dampers. Neither the rates of the springs nor the dampers are capable of being changed by external signals. The suspension is only capable of storing, restoring and dissipating energy; there is no means of supplying external energy to the system.

Passive, self-levelling – This operates exactly as a passive suspension except that external energy is provided to maintain constant ride height of the vehicle in response to changes in *static* loading. Typically, such systems would be pneumatic or hydro-pneumatic and have a delay time of several seconds before any levelling corrections were made.

Dissipative semi-active – A system with the ability to continuously vary the rate of energy dissipation. Typically, this involves controlling the orifices of a damper or the force across some equivalent actuator. A minimal amount of energy is required because the damper or actuator never has to supply energy to the suspension system, it only has to dissipate energy but in a more intelligent way than a passive damper.

Slow-active (Fig 2) – A system in which an actuator acts in series with the passive suspension spring. Such an actuator may be based on hydraulic or electrical components and would have typically a bandwidth of around 3 Hz. It is this limitation in frequency response which distinguishes the slow active system from the fully active system described next.

Active (Fig 3) – A system in which an actuator either totally replaces the conventional spring and damper elements or acts in parallel with a spring. The actuator works according to a force demand signal typically generated from a microprocessor on the basis of measured information about accelerations and displacements of the vehicle body and wheel. This type of system requires a significant amount of energy and the bandwidth is limited only by the frequency response of the actuator and control components, which would typically be hydraulic and of aerospace quality.

Adaptive – An adaptive system is one in which some suspension parameters can be altered in response to a change in the vehicle operating condition (eg. different road surface or forward speed). So, for example, a passive system could be adaptive if a number of discrete spring and damper rates was provided. The adaptive control would select the 'best' spring and damper settings for the particular condition. Thus, for smooth roads it may select soft spring and low damper settings and then switch to high gap spring and damper settings when the vehicle is on a rough road or track. Equally, an active system can (and in fact almost certainly would) be adaptive. In principle, the active system only has to change some feedback constants used in the control law in order to be adaptive and since these are stored in the microprocessor, it is a trivial operation to vary them according to some predetermined plan.

Suspension systems compared

The adjoining panel outlines the main features of different suspension systems.

The principle of operation of the semi-active, slow-active and fully active systems is similar and is summarised in Figs 2 and 3. Transducers mounted on the body and wheel measure information about the system 'states', ie. x_o, x_b, x_w, $\dot{x}_b$ and $\dot{x}_w$. This information is monitored by a microprocessor which then acts according to some pre-programmed control law and issues a demand signal. The actuator and associated control hardware attempts to track this force or displacement demand signal faithfully, operating in the conventional closed loop manner.

The main analytical difficulty lies with obtaining a suitable control law. Mathematical techniques are available for this; the most straightforward, but unfortunately the most impractical, comes from classical optimal control theory. This 'full state feedback approach' requires transducers to measure x_o, x_b, x_w, $\dot{x}_b$ and $\dot{x}_w$.

The force demand signal (U) is then simply,

$U = k_o x_o + k_1 x_b + k_2 x_w + k_3 \dot{x}_b + k_4 \dot{x}_w$.

The optimum k values are those which minimise a specified Performance Index, which in this case contains body acceleration, suspension working space and dynamic tyre load with weighting factors controlling their relative importance.

For the more practical case in which not all the state information is measured, iterative techniques for obtaining a reduced set of control gains are available (Wilson *et al*, 1986). In particular, measuring the ground profile height, x_o, is not an attractive proposition from a practical viewpoint. The same operating principle applies to the semi-active and switchable damper systems, except that the force demand can only be dissipative since such systems cannot put power into the suspension.

Basic design factor is working space requirement

Comparing the performance of competing systems is not a straightforward matter and until recently resulted in great confusion in the literature. However, one technique which has now gained widespread acceptance is to judge competing systems on the basis that they have an equal appetite for

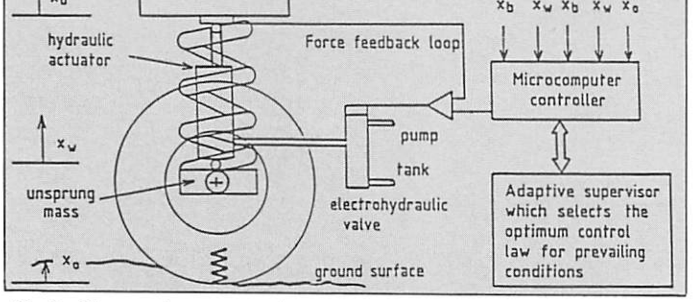

Fig 2. Slow active suspension.

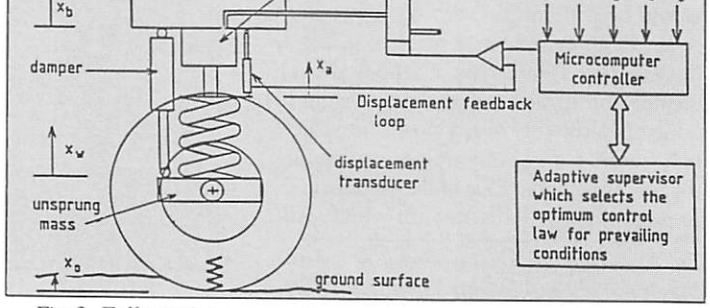

Fig 3. Fully active suspension.

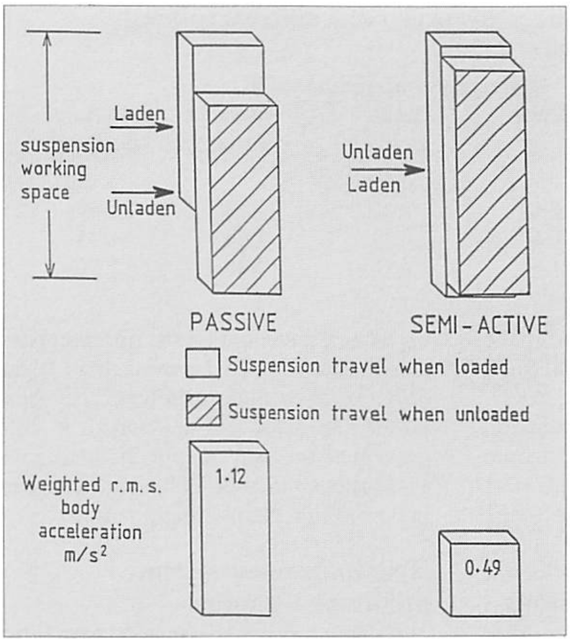

Fig 4. Improvement in performance offered by self-levelling (AFRCIER Test track—2m/s)

working space. This reflects the designer's basic approach to the problem; ie, given this amount of working space, what is the 'best' suspension in terms of the performance criteria already discussed?

Using this approach, **self-levelling** offers substantial advantages over conventional passive systems, the percentage gains being related to the laden/unladen mass ratio of the vehicle. The benefits arise simply from the fact that if there is no static deflection associated with adding the load, then more suspension working space is available and this can be exploited by using a softer spring than conventional. The point is made in Fig 4 for a 12 t prototype farm transport vehicle (FTV) with 6 t payload (Crolla *et al*, 1987)

Thus, there are some significant potential gains available from modest changes to passive systems. The drawback is that vehicle attitude is less well controlled by the softer suspension. A method of counteracting roll and pitch angles arising from cornering and braking manoeuvres was proposed many years ago by Automotive Products (Crolla *et al*, 1987).

This hydropneumatic system incorporating a hydromechanical valve arrangement has proved to be successful on prototype vehicles although it has never achieved commercial success.

The next level of sophistication involves the **controlled suspensions** already described. Predicted results using data for a single wheel station of a typical passenger car (Sharp and Hassan, 1989) are shown in Fig 5. Results calculated using data for the farm transport vehicle have revealed similar trends (Crolla and Aboul Nour, 1988). These predicted results shown in Fig 5 were obtained from calculations in which the quarter car model traversed a random ground profile at three different speed/roughness conditions. The suspension working space usage was exactly the same for all the systems shown. For the active and passive systems, the lines indicate that there are a number of systems with different stiffness, damping or feedback gain values which satisfy this working space requirement.

Advantages of active systems

These condensed results contain several interesting findings which are contrary to some of the folklore surrounding active suspensions.

First, although active suspensions show clear advantages over passive arrangements, the potential improvement in terms of ride performance is at best only about 25%.

Second, the biggest improvements arising from the active suspension occur on the roughest surfaces. A more strict interpretation of this is that the biggest improvements are shown when the ratio of road roughness to available working space is greatest. At the other end of the spectrum on the smooth main road surface, a purpose-designed passive system can achieve similar performance to the active system.

However, there are other factors to be considered in addition to these ride results. The passive system which achieves this performance is extremely soft by comparison with conventional systems so that static deflection and body attitude control would pose insurmountable problems. The comparable active system, however, would overcome both these problems.

A third conclusion is that the slow active system provides similar performance to the fully active one. This appears to be extremely significant from a practical viewpoint because the components associated with the limited bandwidth, slow active system are much cheaper than those for the fully active system, which requires high bandwidth, (aerospace quality) components. Although the layout shown in Fig 3 looks rather impractical, the same principle could be achieved using a hydropneumatic system with a valve controlling the oil flow to the struts, as discussed later.

Fourth, the semi-active system based on a continuously variable damper which is able to track a dissipative force demand shows worthwhile advantages. Such systems, which are currently of great interest in passenger car design because of their negligible power requirement, would almost certainly be used with self-levelling control and some form of roll control system. This would allow softer suspension spring rates to be exploited.

The fifth, and most important, advantage of active systems is a more subtle one. Returning to conventional passive systems, the main weakness is that the designer must choose fixed parameter values, whereas what he would like is to adapt the stiffness and damping values to each

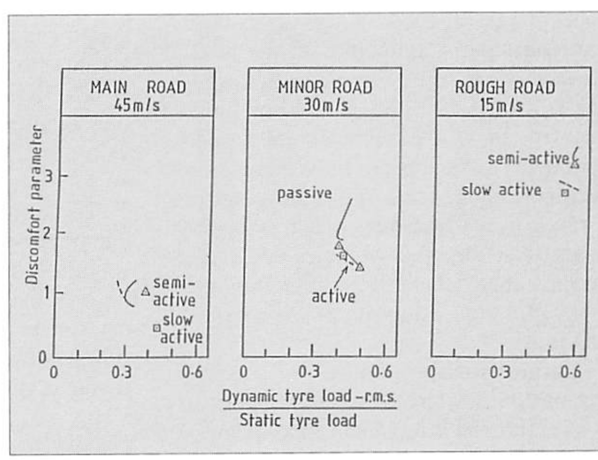

Fig 5. Comparison of various suspension systems over 3 surface/speed conditions element (Suspension working space rms=30mm)

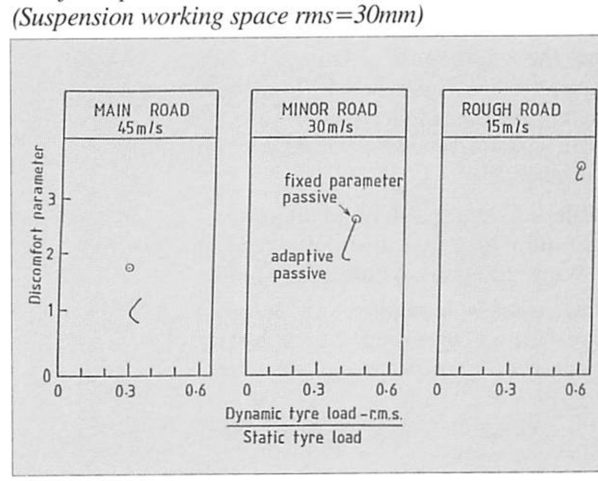

Fig 6. Comparison of passive systems with fixed and adaptive parameter values (Available suspension working space=180mm)

road/speed condition. The benefits of being able to do this are considered as shown in Fig 6.

There are, however, significant practical problems associated with altering the suspension stiffness over the required range. With the active systems, however, there is no problem in building in an adaptation strategy. The 'parameter values' are essentially a set of control gains held in a microprocessor and these could easily be updated as the vehicle speed or road conditions change.

Special considerations for off road operation

There are several features which are specific to operation off the road and which influence the aforegoing comments.

Rough surfaces – Off-road vehicles operate over the roughest surfaces and find themselves, therefore, at the very end of the operating spectrum where the biggest percentage improvements are available from active systems. Thus, as an overall guideline, bigger potential benefits are available to off-road vehicles compared to on-road vehicles.

Range of surfaces – The main design constraint on off-road vehicles arises from the requirement to operate off the road. However, in most applications (eg. agricultural, military, earthmoving, forestry etc.), the vehicles must also operate for substantial periods on roads at ever increasing speeds. Thus, the range of surfaces over which they must travel is far wider than for other vehicles and large benefits are available from exploiting the principle of adaptation discussed previously.

Large working space – Passive suspension designs for off-road applications require relatively low spring stiffness and large wheel travels. This, in turn, means that control of roll angles and static deflections is often more of a problem than for road vehicles. However, it also means that the addition of relatively simple enhancements, such as self-levelling or slightly more complicated ones like roll angle control result in substantial improvements.

Table 1 Comparison of mean power demand with active and slow active systems–at equal dynamic tyre loads

Suspension working space, rms, cm	*Dynamic tyre load parameter, %*	*Mean power demand, W* Active	Slow active
2.5	23	36	39
3.5	23	128	158
4.5	27-29	380	490

Table 2 Comparison of mean power dissipation with different systems – compared at a dynamic tyre load of 23%

Suspension working space, rms cm	*Mean power dissipation, kW* Passive	Active	Semi-active	Slow active	Switchable damper
2.5	1.48	1.43	1.41	1.53	1.40
3.5	1.40	1.40	1.27	1.54	1.35
4.5	1.31	1.51	1.31	NR	1.29

NR = Not recorded

This has already been shown for the prototype FTV (Crolla *et at,* 1987) and military vehicles (Maclaurin, 1983). Similar hydropneumatic suspension systems to those used on these vehicles are now beginning to appear on other off-road vehicles (eg. Chafer SSV spraying vehicles).

Power usage – Recent calculations of power usage are summarised in Tables 1 and 2.

These results refer to a single wheel station for a FTV, and all the components are assumed to be 100% efficient (Crolla and Aboul Nour, 1988). This provides a basis for comparing the fundamental differences between the various control schemes. Also, for both the fully and slow active systems, a conventional passive spring is assumed to act in parallel with the actuator to take the static vehicle load. Although this modifies the values of the control gains, it does not compromise the overall performance of either system.

Three main points emerge. First, for the power-consuming systems, there is very little difference in mean power usage. Second, the mean powers dissipated by all the systems are remarkably similar. Of course, the detailed way in which the power is dissipated must be different in each case to account for the different performances. Finally, because there is an order of magnitude difference between power dissipated and demanded, it suggests that the way in which intelligent suspensions gain most of their advantage is in controlling the dissipation of power.

Hydropneumatic system promising for future

Fully active systems appear to have little commercial future. The costs associated with high quality actuators and servo-valves are likely to remain prohibitive for many years. Switchable dampers are currently available commercially and more sophisticated, controllable dampers look a possibility for the near future. However, on their own, they do not offer enough advantages for off-road applications. They must be combined with self-levelling control, in order to exploit the use of low spring stiffnesses.

Slow active systems look attractive in terms of performance providing they can be engineered at reasonable cost. Although there are many possibilities involving the use of electrical, pneumatic or hydraulic elements (Sharp and Hassan, 1989), a system based on hydropneumatic components looks most promising.

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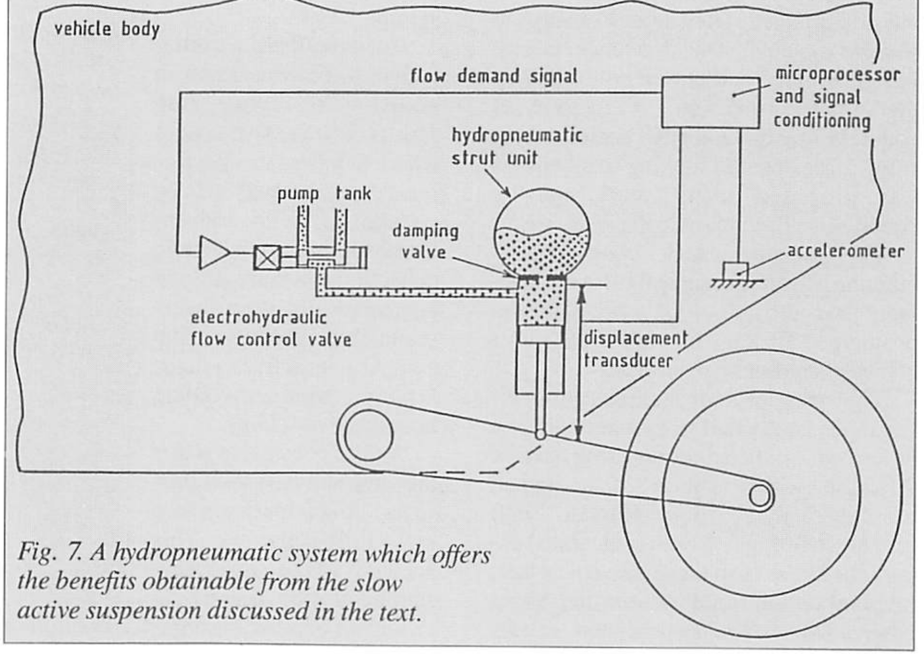
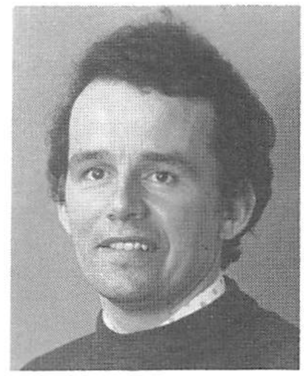


Fig. 7. A hydropneumatic system which offers the benefits obtainable from the slow active suspension discussed in the text.

Vehicle design for stability on slopes



A G M Hunter

Vehicles are used on slopes in a wide range of industries where off-road operations are carried out. In addition to agriculture, off-road machines are used in forestry, construction, defence, transport, grass maintenance and leisure. These machines are primarily designed for function, and stability on slopes may not be assessed.

In fact, design for stability and stability measurement are not straightforward but, where vehicle operators have to cross terrain of ungraded slope, safe operating limits should be defined. In a survey of overturning accidents with agricultural vehicles, Owen and Hunter (1983), found that 55% of accidents occurred on slopes where the vehicle design did not ensure stability. The driver was not considered at fault in any of these cases.

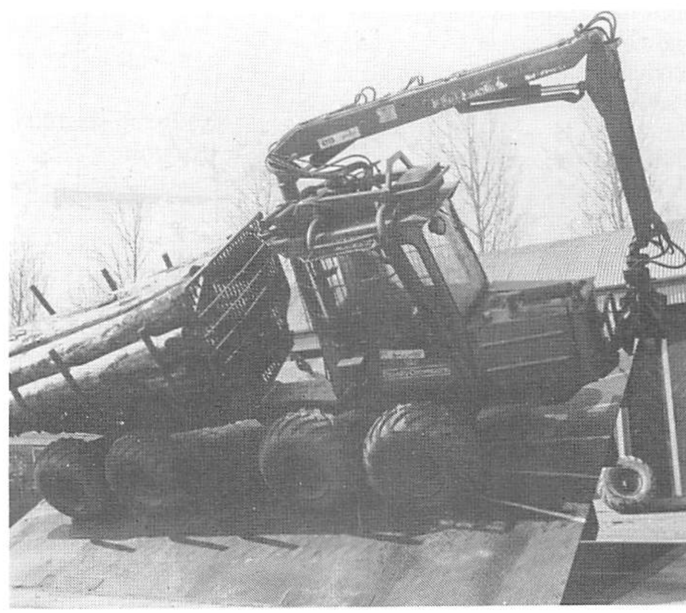
The types of accident which occur have been closely studied (Hunter and Owen, 1983), and a number of safety techniques have been proposed, ranging from considered use of existing equipment (Hunter, 1981) to novel vehicle designs (Owen, 1987). However real improvements are likely to come from the general application of techniques, developed in research work, for assessing stability at the design stage.

The principal approach to analysing static stability of vehicles has been to solve the vector equations of force and moment equilibrium under the particular conditions when the load at one ground wheel has reduced to zero, and to calculate the value of slope for this to occur. Using this method, Spencer (1978) studied a range of agricultural machine combinations, and validated his analysis against the results of physical experiments with scale models. He also analysed the conditions for a vehicle to slide downhill out of control.

Typically, off-road vehicles are unsprung and wheel travel over uneven ground is accommodated by an oscillation pivot that carries a swinging beam for the front axle. With this design, and most others, it is not immediately clear which individual wheel load will first become zero, so this has to be determined as well as the slope angle. In addition, recalculation is needed at each heading orientation on sloping ground.

The results of stability analysis are best presented on a polar diagram (Fig 1).

Measuring static stability of a forestry forwarder on tilt table.



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Many of the components required for a hydropneumatic system have already been proven on off-road vehicles, so the key to extending the capabilities of the system further lies with the development of an electro-mechanical valve to control oil flow. The mechanical valves used in the Automotive Products system which only control body attitude have never found favour commercially. However, if this valve were replaced by an electrically-driven flow control valve then all the benefits offered by the slow active system could be exploited as shown in Fig 7.

Conclusions

Controlled suspensions offer substantial potential benefits to off-road vehicle performance. In several respects these potential advantages are greater for off-road vehicles than for passenger vehicles which have been the focus of attention of developments to date. In particular, the potential for making the suspension adaptive (ie. selecting the optimum set of parameters for each road roughness and speed condition) looks particularly advantageous.

Two systems merit further detailed development for future advanced vehicle designs. The cheaper of these involves soft passive springs, adaptive dampers plus self-levelling (and possibly roll/pitch) control. The more expensive and sophisticated system involves hydropneumatic components operating according to the slow active strategy. The key to the future of this approach is in a low cost, elec trically-driven control valve.

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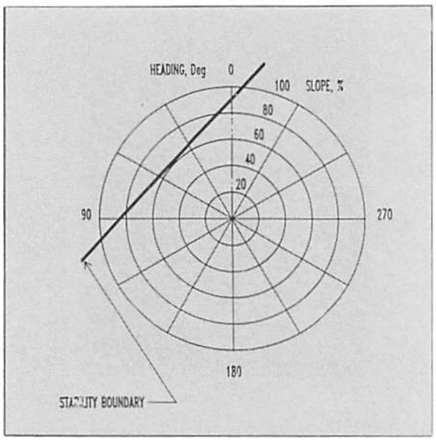

Fig 1. Simple polar diagram.

A single operating point on the stability boundary represents the slope at which a particular wheel load has reached zero for a particular heading angle, and the complete stability boundary summarises the solutions for all heading angles.

Stability analysis may be complex even for simple configuration

The static stability of a slurry tanker is a good example of a case where an apparently simple configuration leads to complex stability analysis (Hunter, 1985, 1986). The geometry of the tanker itself is not complicated, generally with a single axle or tandem axles and a hitch point at the tractor; but the fluid inside will occupy the lowest part of the tank, and the resulting effects of centre of gravity movement on tanker stability can be large.

The effects depend on the tank shape, which may have a circular or rectangular type cross-section, on the tank mounting position, and on the capacity of the tank relative to the weight of the empty tanker. Generally, side slope stability will be affected more in rectangular cross-section tanks than circular ones but upslope stability will be affected in both.

All these parameters are under the control of the designer and an example will show how severe the effects can be when an optimum design is not found.

Fig 2 identifies the stability boundaries for one design of tanker (rectangular cross section) under various states. As expected, the tanker is most stable when empty, with a side slope stability limit of 37°. This limit reduces to 28° when the tank is filled to capacity, primarily due to the increase in centre of gravity height.

However, as the tank empties during slurry discharge onto the land, the stability progressively reduces below the limit when full. In fact the least stable state is when 70% of the tank contents have been discharged and only 30% remain; at this stage the stability limit has fallen to 23°.

For comparison, the stability of a trailer with equivalent solid load is seen to be as high as 35° at the same stage.

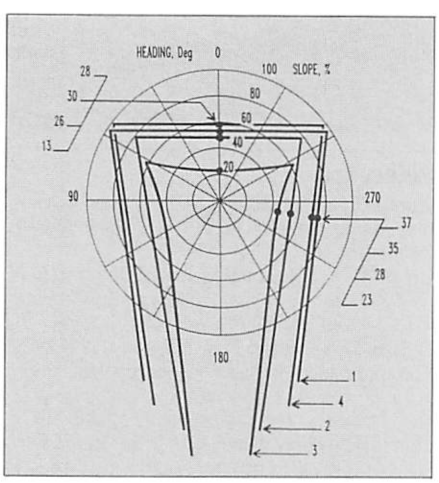

Fig 2. Stability boundaries for a rectangular cross-section slurry tanker.

(1) tank empty
(2) tank full
(3) tank with fluid to only 30% of capacity.
(4) equivalent trailer loaded to 30% capacity with solid material.
Stability limits converted to slope degrees.

Reduced stability may give loss of traction

Considering now the upslope stability, the limit has fallen from 26°, when full, to 13° when 30% full. The significance of this is not that the tanker is likely to overturn behind the tractor but the drawbar load is zero and the tanker will behave as a pure roller which provides no weight transfer. Momentary loss of traction may result in the tractor and trailer running backwards out of control. The above effects will be compounded by tanker content surge.

Stability of articulated vehicles

The basic choice of design can have dramatic effects on static stability. For example, consider a rigid frame vehicle with swinging front axle, and an articulated frame vehicle with roll freedom in the chassis. There are many advantages of the articulated frame design, particularly in improved steering manoeuvrability but, without a detailed search for an optimum design, the stability limit can be severely compromised.

Similar methods of analysis to those for the rigid vehicle have been used by Spencer (1988) to determine the stability boundary for the articulated vehicle, although each different method of providing an oscillation pivot must be considered separately. The pivot may be provided within the chassis, it may remain at the front axle, or it may be transferred to the rear axle.

When an existing rigid frame vehicle

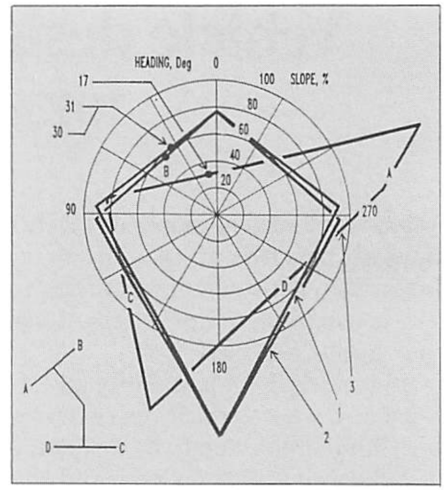

Fig 3. Stability boundaries for two equivalent vehicles.

(1) rigid frame vehicle with wheel steering
(2) articulated frame vehicle in the steer straight position
(3) artic. frame vehicle, full steering lock.
Stability limits converted to slope degrees.

design is converted to an articulated frame design, there first appears to be very little change in the stability boundary (Fig 3); the minimum stability value reduces marginally from 31° to 30°. However, when steered, marked differences appear because, while the geometry of the rigid vehicle is unaltered, the frame of the articulated machine is angled to 40°, and the minimum stability value reduces sharply to 17°.

In the example chosen, the front wheels become least stable when the vehicle is facing diagonally uphill. This combination of direction and least stability is typical for swinging axle tractor designs.

For the articulated machine on full left

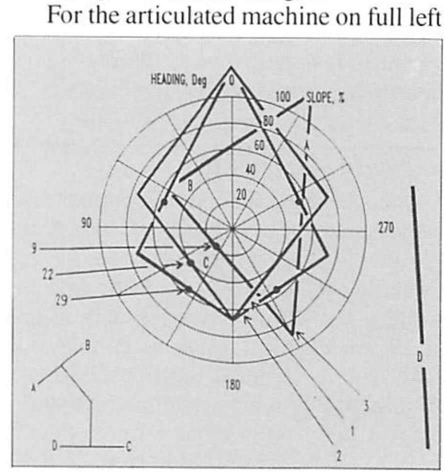

Fig 4. Stability boundaries for the same two vehicles fitted with front loader, loaded with 800 kg, extended to full reach.

(1) rigid frame vehicle with wheel-steering
(2) articulated frame vehicle in the steer straight position
(3) artic. frame vehicle, full steering lock.
Stability limits converted to slope degrees.

lock, only the offside front wheel becomes least stable, and this is when the vehicle is facing almost directly uphill; the nearside wheel does not reach instability unless the slope is considerably steeper than 45° (100%).

Mounted implements introduce further complications

When the two vehicles are fitted with a typical implement such as a front loader, the weight distributions are altered and further differences appear between the two designs.

The stability diagrams are both affected by the greater weight at the front of the vehicle (Fig 4), and stability at the rear wheels is consequently reduced. In fact stability at the rear wheels is now markedly less in the articulated frame design.

When steered straight, the articulated frame design appears to have significant advantages over the rigid machine because the same minimum stability value of 29° occurs at all wheels, a value which is only marginally lower than for the unloaded machine. By contrast, when steered to full lock, there is a drastic reduction in stability.

The least stable wheel now becomes the offside rear wheel and when the vehicle is facing diagonally downhill this wheel is unstable on a slope of only 9°.

An extraordinary feature of this configuration is that there is no heading angle at which the nearside rear wheel can become unstable before another wheel has already done so.

Measurement of static stability

With the tilt table

In addition to calculation, a manufacturer will wish to carry out stability measurements during proving trials. The tilt table offers the most obvious method; it is adjustable to any slope, and the vehicle can be oriented on the table at different heading angles. Counterbalanced lift trucks are tested for stability on a tilt table as a standard method (British Standard, BS 3726), although the test in fact is not related to using these vehicles on rough terrain.

The photograph on page 115 illustrates the use of a tilt table for measuring static stability.

Measurement on a tilt table produces repeatable results; using a two-wheel drive tractor with its axis aligned parallel to the tilt axis, a typical value for the rear wheel stability limit is 37.90° mean, 0.82° standard deviation. Tyre deflection is significant at this slope, and will be related to tyre size and pressure, but the tilt table method takes these effects into account.

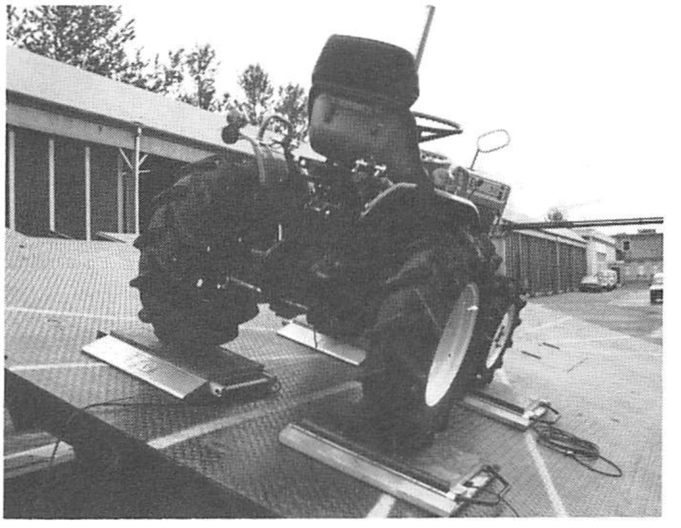

Fig 5. Measurement of static stability using a single weighpad under the uphill wheel of a slurry tanker.

The disadvantages of the tilt table method are high capital cost, and lack of portability.

When the test vehicle is relatively small, like a lift truck, the installation cost for an appropriate size of tilt table is lower, but many off-road machines are large and heavy, requiring substantial investment in the tilt table. The forestry forwarder shown on page 115, is the smallest of its range.

With portable weighpads

The advantages of portability are great when measurements in the field are most practical, eg for a filled silage trailer, or when the plant owner wishes to carry out his own measurements. In the latter case, management may wish to determine safe slope limits for a fleet of forest machines, or grass maintenance machines, and measurement at a local site will be most appropriate.

The portable method of measuring stability was developed during research work when it was realised that, for a particular vehicle oriented along a given heading, the equations for individual wheel load were dependent only on terms involving slope angle. It was therefore reasonable to expect that a prediction technique could be based on wheel load measurements taken at moderate slopes only, and this was demonstrated by experiment (Spencer *et al*, 1985).

The basis of the method is simply to drive the vehicle onto a moderate slope, which is well below the stability limit and is quite safe. The degree of weight transfer from an uphill wheel onto the downhill side is measured with a portable weighpad set into the ground, first measuring the reduced weight when the wheel is uphill and then measuring the increased weight when the vehicle is repositioned with the same wheel downhill. Knowing the slope at the measurement site, and knowing the weight measurements, the value of slope is predicted for total weight transfer, ie for the wheel to become unstable.

The method was used over a number of years on agricultural equipment in the field (Fig 5), and on equipment from other industries.

Lately in order to make the weighpad technique more widely available, a microprocessor-based stability limit calculator has been designed (Owen and Hunter, 1988). This embodies the weight-sensing electronics, the inclinometer, the calculation routines, and the operator prompts which, on connection to suitable weighpads, provides a complete self-contained stability measurement system (Fig 6).

The portable method is now ready for standardisation and work is being carried out to prepare for this, supported by British Standards Institution (BSI). A standard test procedure is needed, the specifications for suitable weighpads must be laid down, the range of appropriate vehicle types must be defined, and the

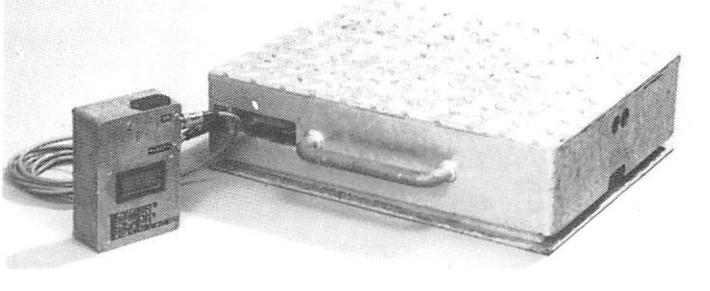

Fig 6. Microprocessor-based stability calculator showing weighpad and attached inclinometer handset unit.

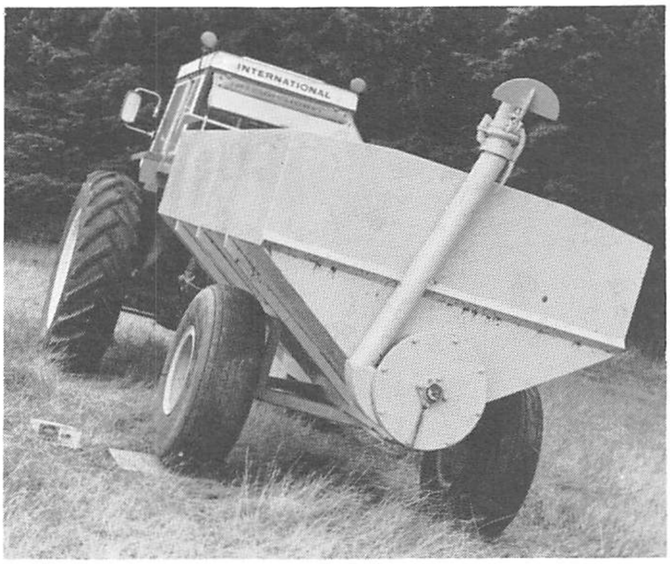

Fig 7. Accuracy experiment for the weighpad method on a preset slope provided by the tilt table.

expected accuracy of the method must be determined. In this work, the tilt table is used as an adjustable platform on which the weighpad method can be fully investigated (Fig 7); statistical analysis is used to evaluate the results, thus yielding the information on which the written standard will be based.

Dynamic stability

When offered guidance on stability limits, the vehicle operator wishes to know the limit under dynamic conditions as well as the static conditions referred to so far.

The least complicated type of dynamic input occurs at steady speed during a constant radius turn on a constant slope. The analytical procedures are similar to those used for static stability, and proving trials can be carried out on a smooth test ground.

The effects of speed during cornering can be severe, for instance causing a two-wheel drive tractor to overturn at a speed of 18 km/h in a turn radius of 5 m on a slope of only 2° (Owen, 1980). Offset centre of gravity due to a mounted implement, and reduced turn radius, will combine to reduce the safe travel speed on a particular slope.

Operators may be aware of these factors but lack specific guidance on safe operating limits.

Behaviour on rough terrain

The assessment of dynamic stability on rough sloping terrain is more difficult, since conditions are no longer steady state.

In order to confine the problem to manageable bounds, Grecenko (1983), for example, carried out measurements of vehicle response to riding over an obstacle of standard shape placed on smooth level ground. Using this approach he has proposed guidelines for safe operation.

An alternative approach is to take an instrumented vehicle into the field and measure its response at different speeds to travel over rough ground on different slopes, and for this purpose a small trailer and a tractor were fitted with wheel load transducers (Owen, 1988). The main advantage of this method is that the random effects of rough ground inputs are included in the measurements and, although the inputs are random, the characteristic dynamic behaviour of the vehicle, when the wheels are on the ground, will be distinctly different from the behaviour when one wheel has momentarily left the ground.

Considering a two-dimensional model (Fig 8), the uphill wheel load vanishes during wheel lift-off, and the angular acceleration of the vehicle is influenced solely by gravity.

In order to examine the validity of the above approximate model, the acceleration responses were measured on the vehicle which was driven over an obstacle to initiate wheel lift-off. It was found that, during lift-off, the acceleration terms summed to zero (Fig 9), identically with the measured wheel load which was also zero, and as predicted by the simplified equations (Fig 8).

On further analysis, it was found that the duration of wheel lift-off has a direct relationship to the maximum potential energy gained, a short lift-off representing an energy input that falls short of the potential energy required for overturning.

The duration of wheel lift-off can thus be studied under varying circumstances in the field, and the energy gains can be related to travel speed and slope.

The results of first field experiments suggest that this method is suitable for determining guidelines on safe operating slope (Fig 10).

For example, at a speed of 9 km/h the energy inputs to the small trailer due to rough ground were only 2% of the potential energy needed for overturning on a slope of 13°, while they were 26% on a slope of 18° (Hunter *et al*, 1988). These test slopes correspond to one half and two-thirds, respectively, of the static stability limit which was 27°.

Stability must be considered at the design stage

For most types of off-road vehicle, stability can now be calculated using accepted methods, and comprehensive results can be presented in the form of a set of polar diagrams.

The principal advantage of the calculation approach to determining stability is that a range of different design options can be explored easily, including a study of the

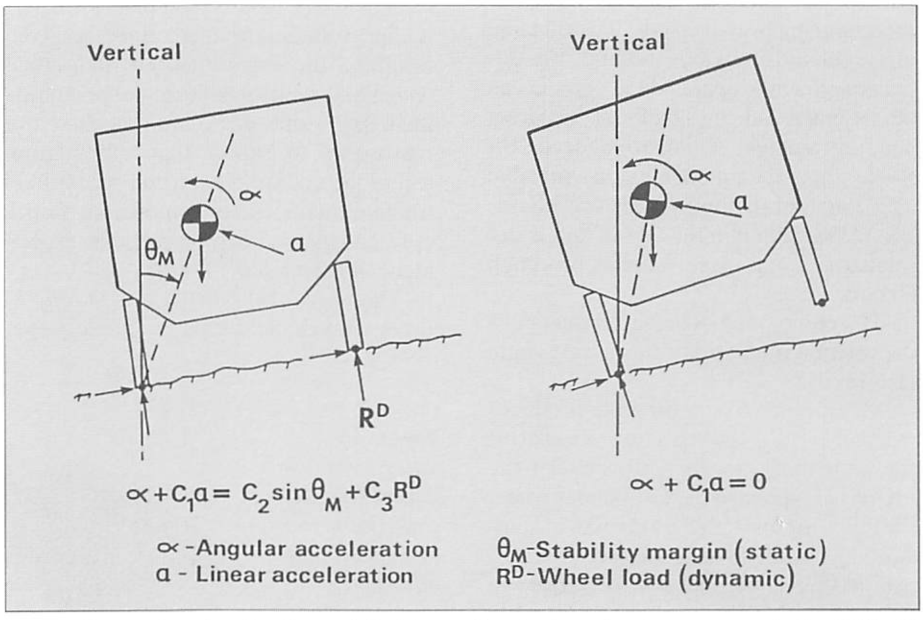

Fig 8. Illustrating the simple model of dynamics during wheel contact and wheel lift off.

sensitivity to changes in design parameters.

The wide range of effects which can occur is demonstrated by the examples given with the slurry tanker and the rigid/articulated vehicle designs.

It is important to investigate the range of possibilities likely to be found in normal operation. For instance, it may be that cross-slope stability when the vehicle is following a contour line is not the most severe case, and the study of stability at other heading angles may be essential.

Similarly, the stability under all potential loading conditions has to be considered; for a vehicle with a front loader, the position of the loader itself may be important, whether lowered or raised, and the least stable position may not be immediately clear by inspection. The stability will be different again if a rear-mounted implement is attached.

It is therefore necessary to investigate stability thoroughly and, where there are a number of alternatives with conflicting stability results, then compromise will be necessary.

The manufacturer may wish to study the alternatives himself using his own analytical programs, or he may find that employing a specialist is more cost-effective.

Customers will welcome stability guide

Stability measurement during proving trials could be carried out more commonly than at present, although it may indeed prove confusing initially. Depending on the results, a vehicle may appear to be adequately stable, and then evidence of low stabilty may appear unexpectedly later. A number of different heading orientations and loading conditions may need to be measured before a full stability picture is built up.

The tilt table will provide a convenient method of measurement if available, but the potential advantages of the portable method are considerable, not least in making a method easily available to all manufacturers.

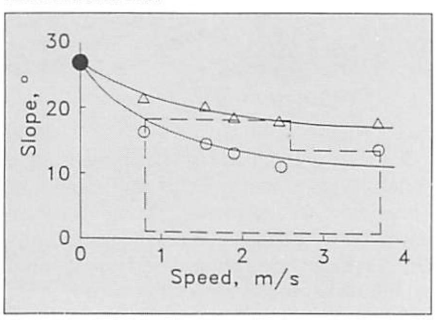

Fig 10. Plot of energy inputs related to field slope and vehicle speed, 2% lower trace, 26% upper trace.

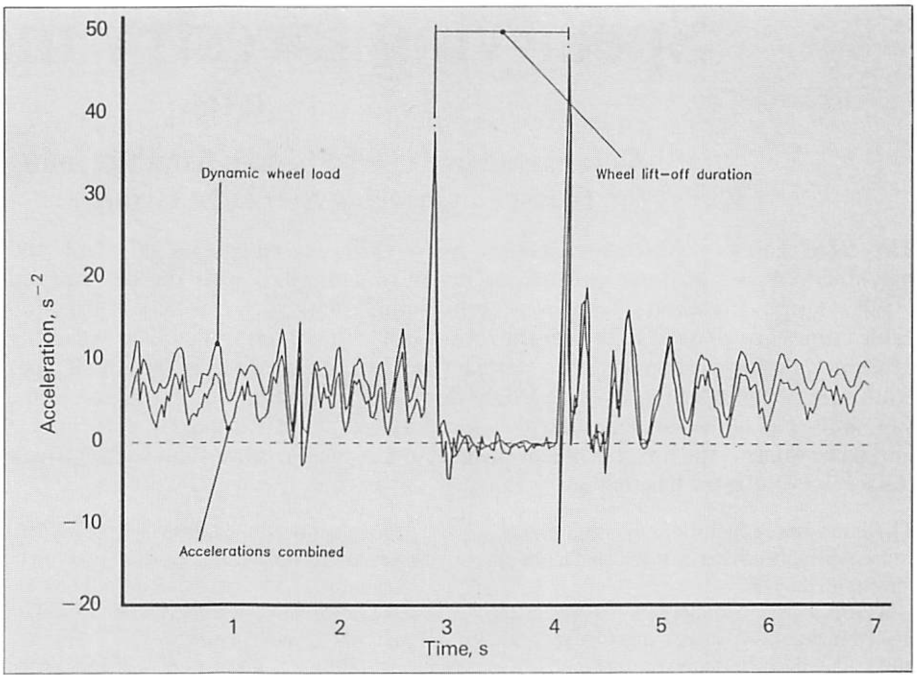

Fig 9. Superimposed plot of wheel load and body acceleration signals showing coincidence at zero level during wheel lift-off.

Stability measurement by the manufacturer as common practice, with advertisement of the results, will be a positive step forward, welcomed by customers, as well as a valuable development tool at the prototype stage.

British standard in prospect

A standardised procedure for the portable method is under development now, leading to a British Standard.

This Standard will apply to a wide range of off-road vehicles in addition to agricultural equipment, and will also cover other aspects of safety on slopes in due course. It is hoped that manufacturers of vehicles for the forestry, grass maintenance, construction, and other industries will find the new Standard valuable.

The first part of the Standard will cover static stability only, and this is regarded as the correct starting point.

When values of static stability are available for reference then the current research work on dynamic stability will become directly relevant.

Users need guidance on the safe operating slope for vehicles; this implies having a set of criteria to determine the probability of overturning under dynamic conditions on a particular slope, relating this slope to the static stability limit. In due course it is envisaged that recommended slope limits will be identified for each vehicle as it reaches the market place, and users will be able to make a clear choice of machine for each application.

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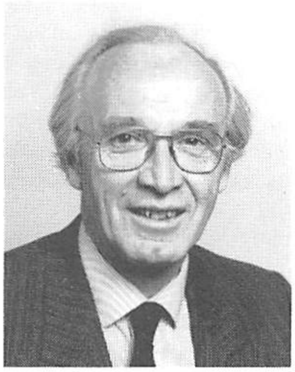
Specifying forestry machinery

R Hay

As reported by D D A Shearer from the inaugural meeting of the Forest Engineering Specialist Group



The term Forestry Machinery covers many different categories of plant and machinery. Some of these will not be instantly associated with the description.

For example, bulldozers, large excavators, dumptrucks, rock crushers, rollers and cable cranes are all included under the forestry machinery umbrella. So are planting machines, timber processors, harvesters, forwarders along with transport of all types from heavy timber haulage vehicles right down to the humble van. In the case of the van, at the end of the list, it is not widely recognised that the transport of personnel to and from work in the forest is one of the greatest expenses, other than wages, which the forestry industry has to bear.

There are many factors to be taken into account when specifying a machine for use in forestry in the UK.

A particularly important factor is that, owing to the comparatively small market for specialist harvesting machines at the present time in this country, no home based manufacturer has yet emerged offering machines which are totally suited to the conditions found here. Machines which are manufactured abroad have to be modified to cope with our forest terrain – this tending to be on poorer ground and steeper and wetter than that generally found in Scandinavia, or eastern North America.

Nevertheless, Scandinavia and, to a lesser extent North America, are the main sources of machines which have been used by the Forestry Commission.

This import situation leads to spare part supply problems and also to problems with prices, both of spares and of whole machines, as currency values fluctuate.

Detailed costing system based on individual machine performance

The cost of machinery and its operation is only part of the cost of timber as delivered to the end user, be it a sawmill, chipboard manufacturer or pulpmill, but it is an increasingly significant part.

In assessing the cost of any machine it is more important to examine the cost per unit of timber handled rather than the operating cost per hour.

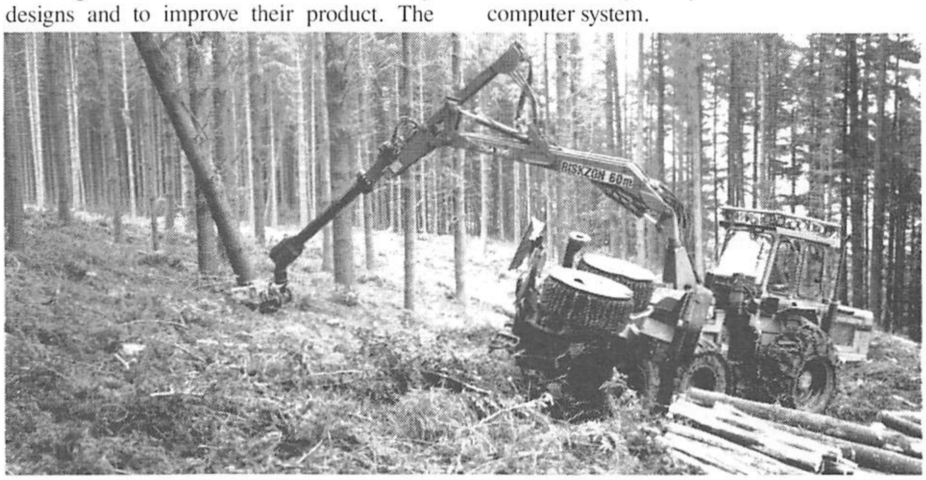
To obtain the whole life cost of a machine the Forestry Commission (FC) operates a comprehensive computer based fleet management system. In this system every machine or piece of plant is allocated an individual fleet number at the time of purchase and all costs and details for that machine are logged against that number.

With the Forestry Commission's plant fleet currently standing at around 4,500 machines with a total value of £60 million, it can be seen that cost control and recordding is a major operation.

From the details gathered by the system, such as the cost of repairs, the spare parts used, etc. all running costs can be examined. These are broken down into categories and presented on request along with machine availability and utilisation figures given as percentages of the total figure possible. The location of repair on the machine such as to the engine, the transmission, the loading crane or attachment is also logged along with comprehensive defect reports. A full analysis of costs and failures can thus be obtained.

Performance data used in specifying design requirements

To give an example of the facts highlighted by the FC fleet management system – it has shown that timber forwarders today are apparently no less prone to breakdown than they were ten years ago. With the back up of the comprehensive data from the FC management system pressure can be brought to bear on manufacturers to modify designs and to improve their product. The records are also used to influence the choice of machine to be purchased as well as assisting in the matching of machines to the requirements of the end-user in the forest.



An OSA harvester felling a P38 Douglas fir. Kintyre Forest District, April 1987.

The specifying of machines and the targetting of problems in this way is now a priority in order to reduce costs through increased machine efficiency.

Some problems can still arise. For example, when a manufacturer introduces a new model this makes the comparison of data on a historical basis a little more difficult due to the differences in the specifications of the new and the old models.

The cost of installing and operating such a comprehensive record system is recovered in the savings made on machine choice and usage based on facts gleaned from the system.

Mechanical timber harvesting set to expand: manufacturers can benefit from FC performance records

With the cost of a timber harvester currently standing at around £200,000, the potential for machinery makers can easily be seen. It is good to see there is already at least one British manufacturer, currently at the prototype testing stage, with a machine designed and specified with Forestry Commission guidance based on the records of past experience held on the FC computer system.

With the forest industry fast approaching a period of major expansion in the volumes of timber harvested and the need to remove manual cutters from the dangers and health hazards present in their occupation, mechanisation of harvesting has to grow at a faster pace.

There will be greater expansion of mechanical harvesting over the next ten years than at any time in the past and these are early days in terms of mechanisation of the forestry industry in UK.

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David Shearer is a freelance technical author and publications consultant from Stirling.

Farm mechanisation in North West Cameroon

E A Baryeh suggests that, in planning a programme of mechanisation, it is important to find out from the start the farmers' views on what is necessary and acceptable.

He reports here on a survey carried out amongst the farmers of the North West province of Cameroon.

Agriculture is the backbone of the Cameroonian economy as it is of most developing countries, yet farming in Cameroon is generally very labour intensive and time consuming, resulting in insufficient food production. The need to increase food production in these countries has been well documented but, to increase it, farming has to be mechanised. According to Davis and Patrick (1981) evidence from Asia and Africa indicates that selective mechanisation can increase both employment and food production.

Although the need for mechanisation has been suggested in various quarters, there have not been any studies in Cameroon to show if certain types of mechanisation would be acceptable to the farmers or not, what kind and level of mechanisation the farmers want and whether the farmers would be prepared to be trained to operate farm machinery.

The studies presented here recognise that in seeking a mechanisation programme, it is necessary to consider the farmers' views on the subject and to evaluate them. Questionnaires on mechanisation were drawn up and tested on some farmers in the North West Province of Cameroon.

Heavy acid soils and high rainfall

The North West Province occupies an area called the High Western Plateau, which has a series of volcanic mountains. Altitude is 800 to 1000m above sea level.

The area is mostly underlain by volcanic and metamorphic rocks. The soil has a pH of 4.5 with some lava characterised by high organic matter content. It is composed of about 45% clay, 15% sand, 15% silt/loam and 25% concretionary stones down to a depth of about 40cm.The phosphorous and nitrogen contents are 40kg/ha and 70kg/ha respectively. It has an average bulk density of 14.5kg/m^3 (Baryeh 1986).

The climate and vegetation are equatorial. The mean annual temperature of Bamenda, the provincial capital, is 22°C. The Province lies in a 2000 to 10000mm annual rainfall region with Bamenda having 2600mm (Gwanfogbe and Melingui 1988). The rainfall is from March to October peaking in June and September. It lies in the Atlantic hydrological basin and is drained by rivers of average size. The climatic conditions are also documented by Hawkins and Brunt (1965).

Administratively, the province has five divisions. These are Bui, Donga-Mantung, Menchum, Mezam and Momo (see Fig 1).

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The cash crops cultivated are palm oil, coffee, tea, rice and cocoa. The main locally consumed crops cultivated are cocoyam, plantain, maize, groundnuts, different types of beans and various vegetables.

All operations by hand

The processes involved in crop cultivation in North West Cameroon are land clearing, land preparation, planting, weed control and harvesting. Farmers practise mixed cropping and some shifting cultivation. Farm sizes range from one to 2½ hectares. Irrigation and the use of fertilizer are virtually non-existent. Farmers rely on rainfall for the water requirements of their crops, hence they normally cultivate one crop per year. Consequently, when the rains fail, there is shortage of food and food prices rise. A few farmers use animal and poultry waste as manure.

The farmers' ages ranged from 35 to 70 years and they were all married. Most of them were polygamists and a few of them (about 18%) had some primary school education. Their dependants ranged from 6 to 25 and they knew little about the luxuries of modern life. They had been farming for several years and all practised mixed cropping, cultivating 2 to 5 crops simultaneously on the same land.

Some questionnaires on farm mechanisation were given to the selected farmers and their responses were entered in appropriate spaces.

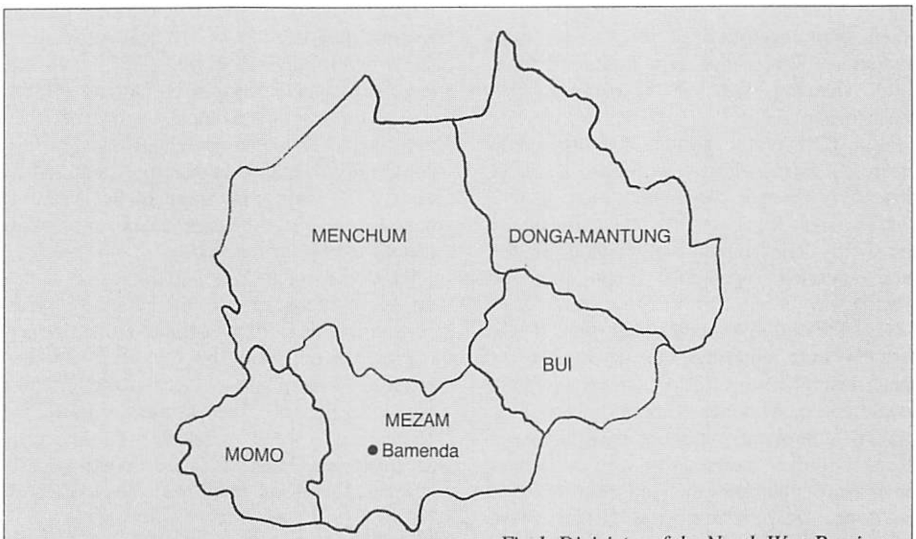

Fig 1. Divisions of the North West Province.

The land is cleared manually with cutlasses, matchetes and hoes, the cleared vegetation being left to dry and then burnt. Vegetable and root crops are cultivated on ridges, mounds or beds made manually with various types of hoes, pick-axes and spades. Planting of seeds, tubers and cuttings is done manually with cutlasses and hoes. Weed control is carried out by cutting with cutlasses and hoes or by uprooting them. Herbicides are not used. The crop is also harvested manually.

Over 95% of the farm power used is from human energy.

Random survey of fifty farmers

About ten farmers were randomly selected from each of the five divisions in the province. The farmers were visited during the cultivation period of March to October.

Some of results obtained are illustrated in Fig 2 which shows the level of mechanisation the farmers are prepared to accept. Ninety per cent were prepared to accept and use small farm machines. The same farmers who accepted small machines, rejected large and/or sophisticated machines. Three per cent of those who were not sure about small machines, indicated an acceptance of large and/or sophisticated machines. Although there are a lot of cattle in the Province, a large majority of the farmers ruled out the use of animal power on the farm and most of them simply said that "an animal is not a machine but food".

Financial help seen as essential

All farmers produced for home consumption in the first instance, selling only when they had excess crop or when they faced financial difficulties. All of them indicated their preparedness to harvest two or three crops a year instead of the usual one crop if this was possible. More than 85% said they were prepared to expand their farms and use irrigation technology, fertilizer and small farm machinery to increase their crop output (see Fig 2). About 75 per cent of those who were not prepared to use new technology indicated their preparedness if government and/or other organisations would finance them. Indeed, most of those who indicated their acceptance had done so on the assumption that government and/or organisations would help to finance such ventures.

There was, therefore, a perceived need for financial aid. This supported Baryeh's statement (1982) that most West African farmers were poor and might not be able to afford the cost of mechanised farming. Some of the farmers who were not prepared for these changes considered their present situation to be satisfactory. Most farmers said that government officials often called to ask questions but afterwards they received no change to their situation.

Mechanisation requirements

Fig. 3 illustrates the level of acceptance of small farm machines for the various farm operations. Surprisingly, few farmers thought **land clearing** was an operation worth mechanising.

Some 62% of the farmers felt they could clear their farms without any problems. out of this, 43% thought they could even clear a slightly larger farm then they had at the time of the survey. This showed that mechanising the land clearing operation might not be worthwhile.

Nevertheless, the author felt that if the farmers were educated on the benefits of mechanising land clearing, more of them would accept it. Some of them did not think beyond a farm size of more than one or 2 hectares so they assumed that with the help of other family members the land clearing could be done. Only 11% of the farmers were prepared to use herbicides to clear the land (see Fig 2) which was reflected in their lack of acceptance of small herbicide applicators as indicated in Fig 3.

Land preparation, however, was viewed differently by the farmers. Older farmers complained of backache during ridge and mound making operations. All of them agreed that land preparation was strenuous, time consuming and that they would be happy and relieved if they had a machine to prepare the land. They all suggested that a government or co-operative tractor should be retained to prepare the land for them.

Over 66% of the farmers found that **planting** of tubers and cuttings was more difficult than planting of seeds, so they welcomed the mechanisation of planting. However, they required mechanised planting not so much for this reason but rather because they felt that timeliness of planting could be achieved more efficiently. Planting has to be done within a short span of time because rainfall can be erratic.

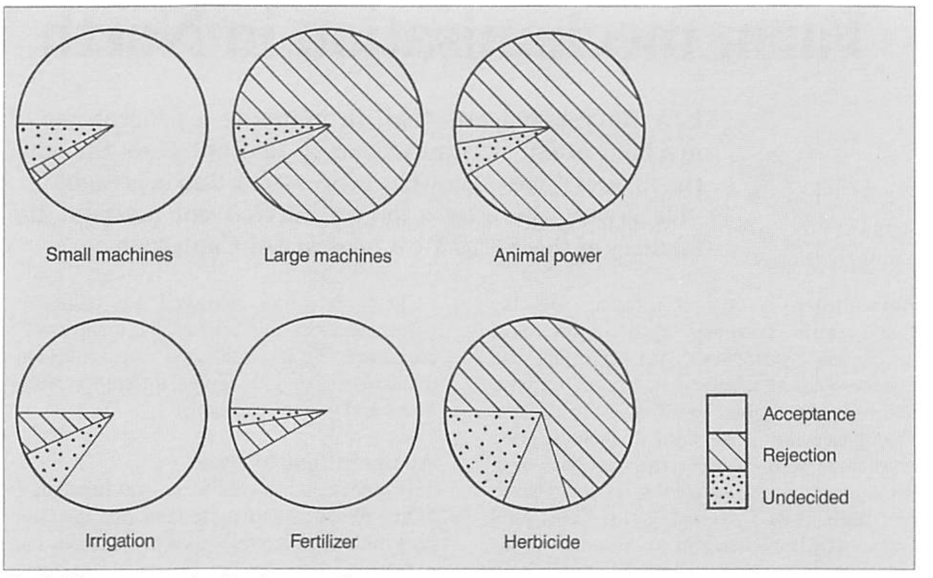

Fig 2. Views on mechanisation practices.

It was, however, considered that as the farmers got used to planters, their attitude would gradually shift to lay emphasis on the labour and time saving aspects.

The farmers were shown pictures of the rolling injection planters developed by the International Institute of Tropical Agriculture (IITA 1980) and Adekoya (1987) and the cassava planter developed by Odigbo (1988). The pictures fascinated them and revealed that they would welcome such machines if they could raise the funds to purchase them either directly or via loans. Some of the farmers, before seeing these pictures, did not even know that such machines existed.

Weed control in West Africa is one of the major bottlenecks in the farming year consuming 50 to 70% of the total man power utilised on the farm (Baryeh 1988) and the farmers' responses confirmed this, consequently, all the farmers opted for mechanised weed control. Those who accepted mechanised weed control also accepted the use of small machines to carry it out. Only 11% accepted weed control by the use of herbicide applicators. This small response to herbicide use was because some farmers considered that herbicides would alter the taste and appearance of their produce and some thought that the crop would absorb the chemical and cause illness when the produce was finally eaten.

After listening to an explanation on the use of mulch to control weeds, 75% of the farmers indicated that they would try mulching, while the rest felt that they would like to see the technique in action before making a decision. They appreciated that mulching was an inexpensive weed control method.

Farmers' views on the use of insecticides and insecticide applicators were similar to those on herbicides and herbicide applicators.

Farmers agreed that **harvesting** was another of the bottlenecks in their agriculture, supporting a similar statement made by Baryeh (1987) and indicated that they would accept the use of small harvesting machines. Some cowpea harvesters (Baryeh, Navasero and Garman 1985; Baryeh 1987) and a cassava harvester (IITA 1980) were shown to the farmers. They were very eager to know more about these as indicated in Fig 3.

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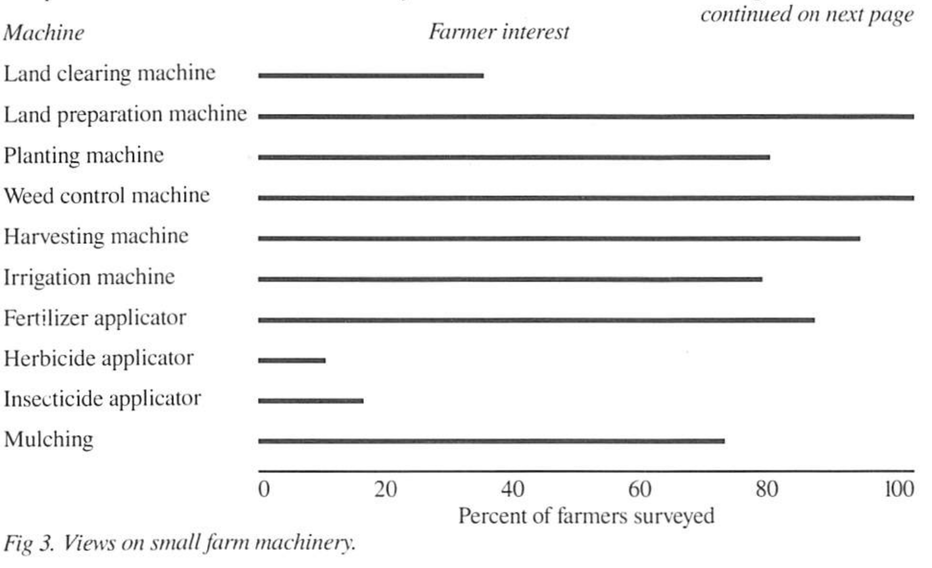

Fig 3. Views on small farm machinery.

Choosing and using farm machines
by Brian Witney

Publisher: Longman, 1988
ISBN 0-582-45600-2 Price £12.95

The area of machinery management is very sparsely covered in the form of text books. Many of these are from the United States and are inevitably biased towards their conditions. It is therefore with great pleasure that I am now able to advise that Brian Witney's book fills much of this gap with a quite excellent text.

The book is in fact aimed at diplomates and undergraduates studying agriculture, agricultural economics, agricultural engineering and mechanisation. However I am sure it will be of great value to farmers and all others involved in mechanisation strategies and whole farm planning. It should be pointed out at this juncture that the content is inevitably based predominantly on work carried out in the UK particularly Scotland. Nevertheless it has many principles which can be converted into any farming system whether it is developed or developing.

The first chapter deals with farming patterns and concentrates on the changes in UK agriculture. This is very well presented, giving a balanced view on all the main issues such as food surpluses, food quality, conservation, animal welfare, labour demand and production efficiency. This is followed by a chapter devoted to operator productivity which deals well with techniques for optimising manpower resources, one small criticism being that the ergonomics is rather overdone for this style of text.

Machine performance and costing is dealt with in the next three chapters. There is of course, some reference to the work of Hunt in Farm Power but this book broadens this considerably and provides a very good reference on machinery costing which is poorly represented elsewhere in the literature. The section on workdays is certainly the best approach I have seen on this subject and provides some excellent examples particularly on spraying forage and combine harvesting. The two chapters dealing with performance and choice are well structured and again are very welcome as being virtually the only text dealing with this subject.

The final chapter deals with fixed cost containment and is a refreshing and well researched approach to this most important area.

To summarise, an excellent text, well presented providing an important link in a poorly represented area in the book scene. My congratulations to the author for producing a text which I am already using as a reference for student courses.

MJH

Biotechnology – Volume 6B
Special Microbial Processes

Edited by H J Rehm
Publisher VCN
ISBN 0-89573-413-3 Price £198.00

This is the sixth part of a set of eight volumes which aim to cover comprehensively the wide field of biotechnology. This volume describes a variety of microbial processes; some established but needing updating; others which have only recently been developed. There is also a look at likely future areas of interest in biotechnology.

A number of chapters pertain directly to agricultural topics. Chapters 22, 23 and 24 describe the post-harvest processing of flax, tobacco and leather, documenting the ways in which micro-organisms and their products are involved in the various processing stages. These sections highlight the potential for further development.

The closing chapter of the volume is entitled 'Biotechnology in Agriculture – An Overview'. In fact, this chapter is a comprehensive review of the state of the art in plant breeding using genetic manipulation. For readers interested in plant biotechnology this chapter will be of value, particularly in combination with the full coverage of processes in plant cell culture provided in chapter 9. Although brief reference to other novel processes are made in the concluding section of this chapter, a discussion of wider applications of biotechnology in agriculture would not have gone amiss.

The preface informs the reader that the chapters in this volume do not fit readily into preceding volumes, and in reality, the volume if judged in isolation lacks integrity. However, in general the individual chapters are well written and presented. The structure of each chapter is excellent, affording the reader a complete analysis of the history, development and current state of the biotechnological processes in question. Each chapter has many up to date references.

This volume contains information of value to a wide range of readers pursuing an interest in novel applications of microbial technology.

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In order to evaluate their level of acceptance for small **fertiliser** applicators, pictures of the fertiliser band applicator (Baryeh, Navasero, Garman and Kang, 1984) and other small fertiliser applicators (FAO 1984) were shown to the farmers. Over 90% indicated that they would accept and use such machines if it increased their harvest. They were affirmative about their preparedness to be trained to operate the machines.

Need for other improvements and facilities

Asked to state improvements and facilities they required on their farms, more than 85% indicated the following: electricity, credit facilities, marketing facilities, financial aids and tractor services (although 35% however did not mention electricity until they were specifically asked). About 65% mentioned good roads, 40% mentioned good drinking water and less than 10% mentioned improved seeds, possibly because many were unaware of plant breeding programmes.

They were also asked to list the strenuous, laborious and time consuming farm operations in a descending order. The majority listed land preparation, harvesting, land clearing, weed control and planting. They indicated that harvesting was not as strenuous and laborious as land preparation but sometimes, it was more time consuming.

Conclusions

From the results of the questionnaire it is concluded that the farmers:

- would accept mechanisation if it involved the use of small farm machines instead of large sophisticated machines;
- would accept the use of irrigation and fertiliser and their accompanying machines to increase their crop yield;
- rule out the use of animal power on their farms;
- indicate the need for financial assistance and electricity on their farms and the creation of marketing avenues for their produce;
- would need to be educated on the use of herbicides and insecticides and on the applicators before they could accept them.

Most African countries have agricultural practices similar to North West Cameroon, except in North Africa where more animal power is used. Due to these similarities in agricultural practices, farmers in other African countries are likely to accept the same levels of mechanisation; therefore, the findings of the study can be utilised by these countries in Implementing the level of agricultural mechanisation required.

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Potential impacts of climatic change in the UK

Protecting people, property and agricultural land from the possible effects of long term climatic change is a top Government priority.

That is the message delivered by the Minister of Agriculture, John MacGregor speaking earlier this year to a special conference, 'The Greenhouse Effect and British Agriculture'.

"Much more information is required," said Mr MacGregor, "on the likely extent and pace of climatic change. The British Government is committed to tackling the problem of research and policy analysis now. Waiting for things to happen will not do."

In this article, M Parry gives an overall assessment of likely climatic changes and their possible impact. On the following page we have a special review of problems that could arise in soil and water management.

Given the present uncertainty about alterations in temperature and rainfall at the regional level as a result of measuring 'greenhouse gases' in the atmosphere, only the most general of potential effects can currently be estimated.

The potential effects are of two types:

- the 'fertilising' effect that increased atmospheric carbon dioxide (CO_2) may have on plant growth;
- the effect of changes in the weather on crops, livestock, diseases, pests, weeds and soil.

Firstly, CO_2 can increase the rate of photosynthesis thus leading to greater leaf expansion, a larger canopy and reduced water losses from plants.

Most crops in the UK will benefit. For a doubling of the atmospheric CO_2 level, yields of wheat and barley could increase by 40% (Cure 1985). There is, however, a downside as weeds also grow faster, pests may consume more and faster growth may need more fertiliser.

Secondly, there are the effects that stem from any CO_2 induced changes of climate.

In the absence of more detailed information for the UK it is resonable to assume that changes in average annual temperatures will broadly follow those best estimates of changes in global temperatures.

If energy use continues to grow as currently projected, the University of East Anglia (Wigley 1989) predicts that temperatures will increase 0.5°C by 2000–2010, 1.5°C by 2020–2050 and 3°C by 2050–2100+ with warming likely to be more pronounced in winter than summer.

The changes in UK rainfall are less clear but there may be less summer rainfall and more winter rainfall in the south and east while in the north and west both winter and summer rainfall could increase (DOE 1988). There is also the possibility with higher temperatures that we may receive more of our rainfall from convective thunderstorms.

Professor Martin Parry has the Chair of Environmental Management at the University of Birmingham.

Opportunities for UK agriculture

Though we should not be complacent, particularly with the high degree of remaining uncertainty, the implications of these climatic changes for the UK do not seem to be as dramatic as in some other parts of the world and in many respects offer opportunities to UK agriculture.

Probably one of the most marked effects of warming would be a lengthening of the growing period.

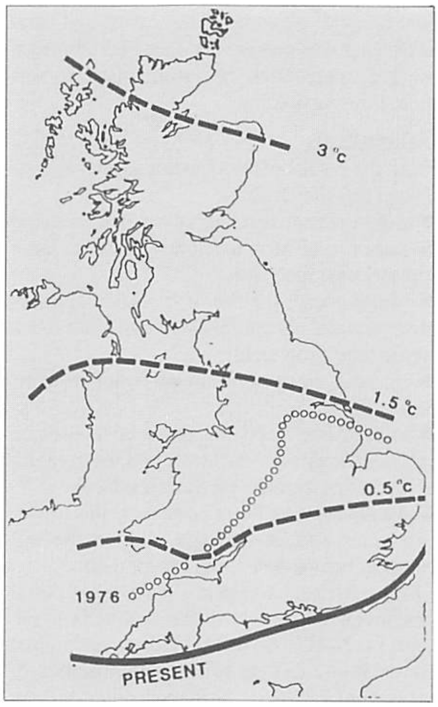

Fig 1. Boundaries for successful ripening of grain maize for three different warming scenarios.

Under a climate in equilibrium, a doubling of levels of atmospheric CO_2 above pre-industrial levels would result in the UK experiencing at least nine months in the year with average temperatures above 5°C and rainfall exceeding half of potential evaporation (save for the extreme south east where the growing season may be interrupted by moisture shortage during the summer).

Present estimates are that levels of atmospheric CO_2 may be double by 2030 but that, due to a time-lag induced by the world's oceans, the full (equilibrium) climate response may not be complete until 30-60 years after that.

Higher temperature would imply that crops which are at present near their northern limit of cold tolerance in the UK would benefit provided sufficient moisture was present.

The boundary for successful ripening of grain maize which is across the extreme south of England would be relocated across central England with a warming of 0.5°C, across northern England for +1.5°C and across north of Scotland for +3°C (Fig 1).

The effect of year to year variations around this average can be quite significant – as illustrated for silage maize by the contrast between a warm year 1976 and a cool year 1962 (Fig 2).

Possibilities for sunflowers, soya beans

Several crops are constrained as much by lack of sunshine and by quite high levels of air humidity as by temperature.

Sunflowers for example are restricted at present to the extreme south of England and here there is still a problem of mildew before the seedhead is fully ripe. But whatever other constraints remain on sunflower growth, their temperature limit may be relocated about 500km further north under a climate that is 1.5°C warmer than the present.

Under this amount of warming it may also be possible to grow soya and navy beans but irrigation would probably be necessary.

Rainfall distribution could shift arable/pastoral line

Much will depend on rainfall changes in annual average amount and its distribution and we know little about how this might alter. We do know that relatively small changes in rainfall could affect the geographical distribution of types of farming substantially.

Currently, the broad distinction between the arable east and pastoral west of England partly stems from differences in rainfall receipt between east and west. A 20% decrease in annual rainfall with the same seasonal pattern and regional distribution as now would shift the arable/pastoral line up to 100km westwards. Would that imply a westward shift of arable farming? Conversely would an increase in rainfall lead to an eastwards shift of land-use belts.

The reality would be greatly complicated by other effects, for example by effects on the availability of water for irrigation in the east and on the existing market for meat and cereals. The indications are that quite small changes in climate could alter substantially the pattern of agriculture potential. It should be stressed, however, that the way UK farmers respond to such changes in potential is another matter.

Upland grassland could give threefold increase

What of the changes in the uplands? A 3°C rise in temperature implies a rise in the potential limit to cultivation of about 500m (1640 feet). Thus, where excessive rainfall and exposure do not continue to restrict farming there may be increased opportunity for cropping in the uplands.

Probably more important would be the extension of the grazing season by one or two weeks in both spring and autumn making it more profitable to improve and maintain upland grassland; and higher temperatures could reduce the tendency for sedge and other rough grasses to invade improved land, making it easier to maintain.

No figures are yet available for the increases in carrying capacity in the UK uplands but recent work in Iceland indicates that, under a warming of 4°C estimated for a doubling of CO_2 the carrying capacity of improved grassland for sheep increases three and a half times and of unimproved range land increases two thirds.

It is important also to consider the implications that changes in temperature and rainfall may have on changes in water for irrigation, changes in soils and changes in the rate of losses to diseases, pests and weeds.

Rainfall – small changes could bring serious consequences

In south east England, in order to offset increased evapo-transpiration under a 3°C warming it is esimated that rainfall would need to increase by 10% if shortage of water for use in agriculture is to be avoided (Beran and Arnell, 1989). The increased costs of water that might result could affect the amount of water used not only in irrigation, but also in spraying and in washing fruit and vegetables.

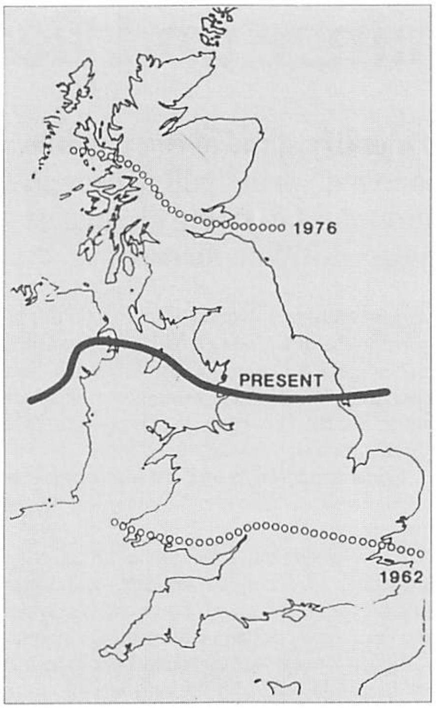

Fig 2. The effect of year to year variations in temperature on the geographical limit for silage maize.

The cost of construction of irrigation systems (in the order of £1,000 – £3,000 per hectare) could be one factor encouraging the westward and northward shift of cropping patterns.

Reduced runoff in dry areas could reduce the dilution of waste, particularly of pesticide residues, with effects on toxicity levels of streams and thus on wildlife.

In the uplands, increased winter rainfall could increase leaching and reduce the pH of soils, and also increase the risk of flood and erosion.

Effects on soils depend much on the future seasonal pattern and intensity of rainfall, about which we know very little at present.

An increase in thunder showers might augment runoff, thus increasing flooding and soil wash. But it also might reduce percolation thus decreasing the amount of soil water available for agriculture. Increased rainfall could increase the mineralisation of organic nitrates, allowing extra plant uptake; but it could also increase leaching downwards of soil nutrients.

In any case, quite small changes in rainfall could require sensitive alterations to the drainage of soils.

Weeds, diseases, pests

We can only guess at the implications for weeds, diseases and pests: warmer winters would extend the growing season of some weeds. For example, corn marigold which flourishes in warmer and damper weather, could become more of a problem.

Diseases which tend to break out more frequently in warm, damp conditions could also increase such as rust, take-all and rynchosporium in cereals, and rhizomania in sugar beet. Warmer winters could also increase the over-wintering of pests, and increase their range. This could affect populations of aphids, pollen beetles and slugs.

Rise in sea level – but time to adapt

The present scientific consensus is that there will be a rise of 0.2m to 1.5m in mean sea level by about 2030. This will lead to a rise in fresh ground water levels which could waterlog low lying soils. There is also the possibility of intrusion of salt water into groundwater in coastal regions and backing up rivers and estuaries, both of which could reduce the availability of water for irrigation.

In general the effects of sea level rise on UK agriculture seem to be negative. But at least the expected rise will be roughly constant over the next few decades and at a rate (probably about 10-15 centimetres per decade) that should allow us time to devise means of minimising damage.

Challenges and opportunities for UK

In reality the future of agriculture in the UK will depend very much on changes elsewhere, particularly in the present bread baskets of the world. There is evidence that higher temperatures and reduced moisture on the Great Plains of the USA and the Canadian Prairies could reduce production and the amount for export, providing an opportunity for increased trading on world food markets by European farmers.

While there are many uncertainties about how our climate will change in future there is one relative certainty about modern agriculture and today's farmers – it is that they have shown themselves capable in the recent past of adapting to a very wide range of conditions both economic and environmental. The question then is not so much "Can UK agriculture adapt to the Greenhouse Effect?" but "What kind of adaptations would be most appropriate and how can scientific research and government policy best help this process?".

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Climatic change and field drainage

A C Armstrong, D A Castle seek to identify some of the possible effects on the way soil water is managed, principally through drainage, but also including irrigation, and in doing so suggest some of the areas where further research will be focused.

In considering the effects of climatic change and the consequent direction for future research two major areas of concern are identified:

- the efficacy of existing drainage installations,
- the effect of climatic change on design criteria.

Since it is not yet possible to measure the change in climate, all discussions of the amount and the direction of change are dependant upon predictive models attempting to predict the climate of the future given increases in the carbon dioxide content of the atmosphere.

There is no single model, nor are the predictions of the various models unanimous in their predictions. However, the majority are agreed that the overall effect will be a global warming of as much as 3°C by the year 2050.

Most models predict that the mean shifts in the temperatures of the UK will follow the global mean, and so the first effect to be expected is an overall warming of the climate. Warming, but not a metamorphosis – so that hot dry summers may become more common, and very cold weather in winter may be rarer.

A climate similar to that currently experienced in Southwest France is generally predicted.

Rainfall – more in winter; perhaps less, but more intense in summer

However, the modellers vary over their predictions about the rainfall in UK. In general, they predict a rise in the mean winter rainfall by about 10%, but predictions of summer rainfall are almost equally split between those predicting an increase and those predicting a decrease. Until better models are built, it is necessary to contemplate both possibilities.

Rainfall intensities, which are important for drainage design, are even more uncertain. However, it does seem possible that intensities will increase, at least at some times of the year. A warmer atmosphere can hold more water vapour, and a warmer summer is more likely to generate more thunderstorms, so it seems probable, though by no means certain, that more intense summer rains will result.

Soil water management becomes even more critical

However, these predictions (higher temperatures, more intense summer rainfall and possibly less overall summer rainfall) all point in the direction of a higher soil moisture deficit in the summer months. We seem to have to plan for a more vigorous climate, in which more rainfall in winter is accompanied by a drier summer.

Under these conditions, the management of the soil water will be even more critical than at present.

Cultivations will have to be timed more precisely, so access to the land will be of crucial importance, and this points to greater demands being placed on the drainage system.

Equally, water shortages may have to be met by irrigation water, so the on-site collection, storage and re-distribution of water will become increasingly important. In all these, existing skills and techniques will need to be exploited to the full.

Narrow drain trench may be inadequate

Increases in either total winter rainfall, or summer rainfall intensities, will lead to increases in the volume of runoff that the drainage systems are required to carry.

Pipes that receive more water than their design capacity become surcharged to an unacceptable level as water builds up over the pipe. Such surcharge may lead to the submergence of mole drains or even to localised flooding.

Recent research by the Field Drainage Experimental Unit (FDEU) has already indicated that pipe surcharge may lead to problems with the longevity of mole drainage with preferential collapse at the point of entry into the pipe system.

The adoption of narrower pipe drain trenches, whilst achieving an economy in the use of permeable backfill material, reduces the storage within the trench and also increases the risk of surcharge occurring. Such trends are rendering installed systems less tolerant to changes in rainfall intensity.

Mole drains may be shorter lifed and fewer opportunities for moling

As well as the possibilities of submergence, other problems with both mole drainage and deep subsoiling, fall into the two categories of installation and longevity.

Conventionally mole drainage is installed at a time when the sub-soil is plastic, but when the topsoil is brittle, leading to a combination of stable channel formation and good crack development, while leaving the surface undamaged. Deep subsoiling, on the other hand, should be done in conditions where cracking and fissuring is the dominant process, and also above the 'critical depth' at which soil deforms plastically to form a channel. Work at Silsoe College (Spoor, Leeds-Harrison, 1986) has done much to indicate ways in which it is possible to adapt the equipment to make the best use of the available soil conditions.

However, a change in the climate may alter the frequency and timing of conditions which are suitable for mole drainage or subsoiling.

Even if the machinery can be adapted to the changed soil conditions, it is not clear that operations can still be successfully undertaken. If a site is too wet, then they cannot be undertaken without surface damage, if it is too dry, then draught requirements become prohibitively large. Consequently, changes in the climate could move the 'window' that is suitable for such operations, perhaps to the point that they no longer become a viable option.

Under these circumstances a change of land use on those clay soils that rely on these drainage treatments may even be dictated.

Mole drainage life is also affected by the climate. In general, mole drain life is shorter

Soil water management becomes even more critical. Dr Bryan Davies, ADAS Regional Soil Scientist, explains the purpose of a 'soil pit' and the information it discloses for good management.
(Photo: Silsoe College)

Dr Adrian Armstrong is a member of MAFF Field Drainage Experimental Unit, Cambridge. Douglas Castle is Head of the MAFF Field Drainage Experimental Unit.

in wetter regimes, because of the longer period of activity. However, it was also observed that the development of very large soil moisture deficits in the 1975-76 drought led to premature mole drain collapse.

The suggested change in climate to a combination of wetter winters and drier summers suggests a reduction in the expected life of mole channels.

Increased winter runoff may demand major changes in river and flood control

Shifts in either the total volume or the intensities of rainfall events, or the frequency of either saturated or dry soil conditions will affect the rate of runoff from small catchments. Structures such as culverts and pipe ditches are frequently designed to accommodate flows from agricultural catchments using the procedures described by Bailey *et al* (1980).

If the climate changes, many of these small structures, as well as the major structures for river and flood control may be required to accommodate higher flows. In some cases, costly replacement may even be necessary.

Where land is drained by pumps, then an increase in the total winter runoff will almost certainly dictate an increase in pump capacity to maintain existing standards of drainage. This problem will be exacerbated by the rise in sea level which is predicted as a consequence of melt water from shrinking polar caps adding to ocean water volume. It is possible to envisage pumps being required to lift larger volumes of water over greater heights.

Effects on overall farming systems

Access to the land is crucial for much arable agriculture. Even small shifts in the length of time that land is workable in critical periods, may have significant effects on the overall farming system. For example Armstrong (1987) has shown how quite small shifts in the number of workdays available, attributable to drainage, can reduce the total power requirement for the cultivation of winter wheat.

Reversing the argument, a decrease in workdays will almost certainly impose a penalty in terms of increased machinery requirements, and also reinforce the need for drainage to maintain a productive agriculture.

Effects on drainage design criteria

In the current drainage design methods, described by MAFF (1982) and Castle *et al* (1984), mean rainfall values are derived for each area, the design standard is defined in terms of a target water-table depth and the risk defined by the recurrence interval of the rainfall event that must be controlled to that target.

A changed climate will of course alter the rainfall statistics that are used in the design, but it can also impose changes on the design criteria that are considered appropriate.

If, as a result of climatic warming, there is a shift towards more high valued crops, notably horticultural crops, which are more sensitive to waterlogging, then the target water-table depth may well be lowered, and the associated risk that can be tolerated may be less. Equally, if crops experience an increased frequency of water shortage in the summer, it may be necessary to design drainage schemes that take into account irrigation needs.

Even if the climatic means do not shift significantly, but the rainfall patterns become more variable, this also can alter the degree of risk adopted in drainage design procedures.

Certain operations will always be critical in the farming calender, and there will always be times when access to the land is at a premium. If the average length of this 'window', or the reliability of the weather within that period alters, then it may be that the standards required of a drainage system be increased.

Probably the most important change that will affect drainage design will be structural changes in agriculture.

New crops, new management practices, and new risks, all within the context of a greater concern for the environment, will impose strict demands on our water management systems.

Changes in economics of drainage

If the climatic inputs alter, and/or if different drainage design standards are imposed, these will have implications on the economic viability of drainage. Improving the drainage capacity, by increasing pipe diameters, by decreasing pipe spacing, or by increasing the frequency of mole drainage, will tend to raise drainage costs. At present some 60% of soils in England and Wales rely on some form of artificial drainage to maintain their productivity. The consequences of a change in the economics of drainage will have an impact on a wide range of agricultural enterprises.

Additionally consideration needs to be given to the wider issues of the implications for crop yield, and the global patterns of crop production. Those studies that have examined such issues, all however seem to point to the future as one in which British agriculture will be faced with the challenge of new crops and higher demand, all within the context of a greater concern for the environmental impacts of agriculture. In terms of water management, these add up to a new era of precise and effective control, in which the efficiency of existing procedures needs to be improved, and their effects more fully understood.

Future Developments

Most of the interactions between climatic change and drainage performance can be tested using computer models. These will require the input of altered climatic values into existing models, in order to identify the direction and magnitude of changes. A programme of this work has been initiated at ADAS FDEU and results will be reported as they become available.

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continued from page 110

Development prospects

This paper has touched briefly on a wide range of current developments. In summary, the forecast is:

- Engine development continuing at a steady pace.
- Power shift development also continuing with the twin objectives of reaching good shift quality under all working conditions.
- Automatic transmissions gradually joining the upper power and specialist user ranks.
- Interactive vehicle controls continue their development in order to realise a potential for improvement for the whole vehicle system which could be 10–30% better than today.

Acknowledgement

May we thank Ford New Holland Limited for their agreement to our presenting this paper. We thank our friends and colleagues for their views and reactions, some of which are buried deep within our paper. They all will be pleased to know that we acknowledge our responsibility alone, for the opinions expressed.

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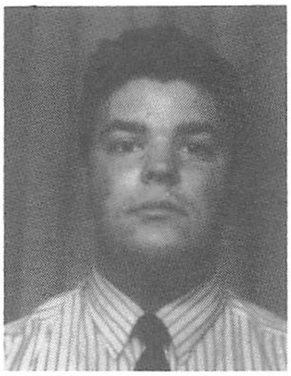
Agricultural engineering in Germany and Holland

I Livingstone reports on the 1988 summer tour of the Young Engineers Section



This first tour of the Young Engineers Section took place in July of 1988 and can certainly be recorded as a success. Those involved in the organising of the tour must be congratulated for arranging visits which were varied and interesting to all who took part. Not only was the tour a holiday for many of us, it was indeed also educational, allowing us to see a range of engineering production, manufacture and research techniques which many of us would not have the opportunity to come across in our present lines of work.

The Claas factory at Harsewinkel

On arrival in Germany the first visit was to the Claas factory in Harsewinkel. The visit commenced with what we were told was a true German welcome; everybody was offered a large glass of milk.

Having been suitably refreshed, a short history of the company was given showing the rapid growth from three brothers with a small workshop in 1913 to today's factory which covers almost 40 hectares and employs up to 5700 people. The success of the company was originally due to their first patent, the double lip knotter which is now the Claas emblem.

Our tour round the factory showed that a large amount of investment has taken place, particularly to introduce robotic welders, multi-head machine tools and laser sheet metal cutting equipment. As with the other companies that we were to visit, Claas like to keep a very tight control on the quality of their products. This means that each combine has to undergo 228 complete tests of all the working parts as well as tests for torque and power for each engine which may last for up to 30 minutes.

After a typical German lunch laid on for us by the company, we moved across to the spare parts building. This store is reckoned to be one of the biggest of its kind, covering 28,000m^2. This could be partly due to the fact that the government insists that there be a supply of spare parts until at least 12 years after production of any model ceases.

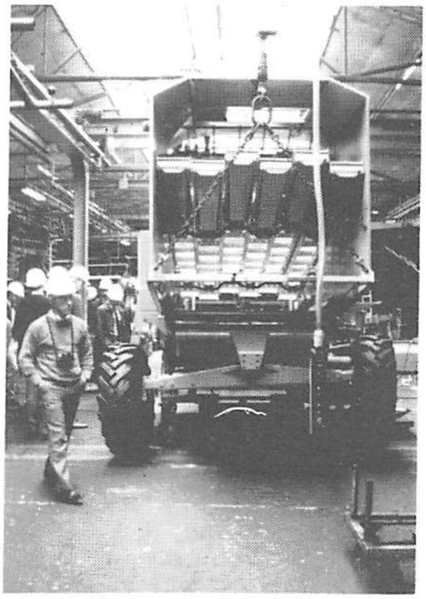
Robotic milking machine at Duiven

On our second day, we moved on to the experimental dairy farm belonging to the Instituut voor Mechanisatie Arbeid en Gebouwen (IMAG) involved crossing the border into Holland and travelling a short distance to Duiven. The 40ha farm supports a herd of 75 Holstein and Friesian cows. The experimental and developmental work at the farm includes dairy automation, forage harvesting, manure handling and animal housing.

Iain Livingstone has been appointed Agricultural and Horticultural Engineer with the South East Electricity Board in Kent. Previously he was Development Officer at the Centre for Rural Building, Aberdeen.

The greatest proportion of time and effort, however, is being put into the dairy automation work with the aim of producing a fully automatic milking system based around the Melkrobot, a robotic milking machine. Although this project is still at a fairly early stage of development, a lot of the finance is apparently coming from industry, and it is hoped that further financial support can be achieved from industrial partnership in order to have the robot in production by the year 2000. Included in the project, apart from automatic milking, are ways to detect oestrus in the cows, bacterial counts and milk temperature measurements, all by means of sensors within the milking cluster.

Another project at the farm is an investigation of the forage intake of cows. An automatic computer controlled feeding system identifies individual animals, weighs out a recorded amount of forage, delivers this to the feed station in which the cow is located and then weighs any left-over feed after the cow has finished. The computer can record all the details of each cow's forage intake and information is also available on the animals's weight, taken from an automatic weighing system.



The visit to the Claas factory.

Short term wilting for better silage

The forage handling work at IMAG is concentrating on the use of mower conditioners to help maintain high quality silage and reducing the high risk element associated with long wilting periods.

The system now proposed involves wilting the silage for only 12 hours instead of the 3-5 days presently being used by many farmers. With the use of a mower conditioner instead of just a mower they reckon on achieving a 5% increase dry matter. The silage is tedded twice a day before being windrowed in the afternoon and ensiled the next day. If the silage has a dry matter of less than 35% within the first day it is ensiled but additives are used, usually formic acid. Molasses can be used but this is far more difficult to distribute.

Unlike the UK, virtually all of the silage in the Netherlands is ensiled in small clamps on concrete floors, often in the fields and with the silage being made with the use of precision chop harvesters. Very little of the silage made is baled, and then only in large square bales.

Animal housing did not seem to form a large part of the Institution's current work, but we did see one building where trials are being undertaken to look at ammonia levels from using different forms of slurry control.

Vredestein automate tyre production

A second visit to Holland took place the next day when we went to the Vredestein tyre factory, in Enschede. The company is expanding with most of the profits being re-invested to provide automated facilities.

As we toured the factory it became fairly obvious why automation was such an important part of the company's policy. Large numbers of people were often involved in some very simple jobs which could easily be done by machine. We noted that, particularly at the start of the production operation, there was a clear need for some automation of the raw materials handling. Despite this the factory was in general remarkably efficient and has a high standard of quality control with each person having his own stamp on individually produced tyres, thus enabling any defects to be traced right back to the operator.

At present 80% of Vredestein tyre output is for the car trade and the other 20% for the agricultural market. This amounts to about 4 million tyres a year which the company hope will be increased to 5 million in the near future. However there seems to be no increase in the demand for agricultural tyres. This may change, as there is some development work being carried out on a new tyre for this market, but there was very little information being made available to us on this work!

Correct tyres and more of them to combat soil compaction

Vredestein seem to be genuinely concerned by such problems as soil compaction and other damage and hope that the information they supply to farmers and dealers will ensure that correct tyres are fitted to tractors and implements in order to reduce these problems. One of the main ways they suggest is to use equipment with more axles rather than relying entirely on large flotation tyres in order to combat soil compaction. This may have something to do with their sales figures rather than a concern for the soil! Vredestein at present have a 12-15% share of the UK agricultural market and they are keen to increase this, both with existing ranges and new products.

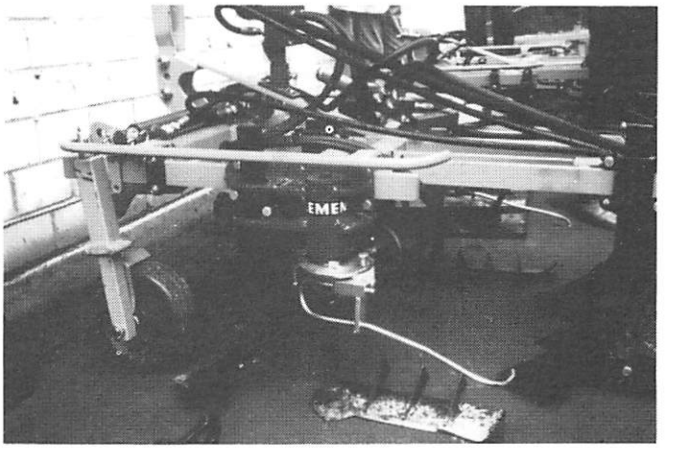
Bonn University's Agricultural Engineering Department was next on our itinerary but regretably this visit was severely curtailed owing to transport problems. Mention can be made, however, of work there on a fairly simple land driven seeder which can be used for planting up to 80,000 plants per hectare. We also saw a modified ATV bike which has been designed to carry equipment for soil penetrometer work. The other major interest the department has is sugar beet harvester technology.

Clemens — vineyard machinery specialists

At Wittlich, near Trier, we visited the family business of Clemens, specialists in machinery for vineyards, row crops, hops and orchards. Founded in 1952 the company has expanded steadily and prides itself on having highly skilled staff and a strong training programme. There are presently 20-30 apprentices in its 150 staff, two of whom are Federal champions in craftsmanship. In addition to the skilled workforce there is a gradual move to automation with a 32 head CNC lathe on site and plans for robotic welders. These machines are used, along with the skilled labour force, to produce as many parts as possible within the factory, including hydraulic control valves.

Weed control and soil loosener

For vineyard use the company has developed several machines including winched ploughs, a weed chopper than can work at speeds of 5-7 km/h and pan busters. In particular, the weed chopper has been very successful as it controls weeds between the rows of trees and vines but also between the trees in each row. An angled blade chops the roots off the weeds as it is drawn through the ground with the added advantage of also providing some soil loosening properties. To enable the blade to work between the trees it is carried outwards from the main body of the machine. On approaching a tree an arm mounted above the ground and slightly in front of the blade causes the hydraulic system to swing the blade out of the way before its comes in contact with the tree. The small pan buster was developed to combat the serious problem of compaction which is often found in vineyards and orchards.



The Clemens weed chopper also provides some soil loosening.

At the final stage of wine production, Clemens have been responsible for the design and manufacture of amongst other things, corking machines, small bottle filling lines and bottle labellers. These machines have proved very popular and the company has managed to obtain fairly substantial export sales as a result of this (including the UK), as well as requring a large part of the home market.

John Deere tractors at Mannheim

The final visit of the tour was to the large factory in Mannheim to see the production of John Deere tractors. The factory is now the largest JD factory outside the United States and covers a 46 hectare site almost in the centre of the city. The factory was originally the site of the Heinrich Lanz factory which produced the famous German Bulldog tractors. The Lanz company was merged with JD in 1956 and substantial growth has taken place since then with the factory now producing 45,000 units per year ranging in size from 38 to 148 hp.

All the tractors now have disc brakes and all have lower link sensing draught control with many other features either standard equipment or optional, such as front PTO and linkage gear.

The factory employs 4300 people of whom 50% come from countries such as Turkey, Chile and Ecuador. These workers are not spread evenly through the work force but tend to be found in areas of poorer working conditions such as the foundry. Foundry production is around 350 tons cast iron per day, from four furnaces. The engine blocks are the only major component not cast at Mannheim. These are imported from another of the company's factories in France. The Brinell hardness test is applied to 100% of all large castings and to 5% of all small castings.

Within the factory there is a high level of automation, particularly where high standards must be achieved, such as in the manufacture of gears. The gear hobbers are fully automatic and are used for cutting involute and helical gears. Further along the production line, metal surfaces are hardened by temperature controlled protective-gas furnaces or by induction hardening in the case of gears and shafts. All drive shafts and crown wheels are kept in their own pairs throughout the production line from manufacture through to assembly to ensure that they match properly in operation.

Cabs for John Deere tractors and combines are manufactured at Bruchsal, 45 km south of Mannheim. The cab production in Bruchsal is lined up in parallel with the transmission assembly in Mannheim. Thus all cabs are ready and waiting for each tractor as it reaches the end of the assembly line. The cabs are reckoned to be one of the quietest on the market with noise levels of 72 dBa on average.

As in many factories today, the tractors are manufactured to order; therefore there is a large range of tractors on the assembly line at any one time. To minimise the number of parts required on the assembly line, a computer system ensures that the right parts are delivered to the correct section of the assembly line at the proper time. The whole process is organised in such a way that it now takes only 27 hours to assemble a tractor, including engine tests on the assembly line and re-testing after the wheels are fitted.

The farming and the countryside

The visit to the John Deere factory finished the official visit to Germany and Holland, however we then had a chance that afternoon and the next day, when travelling back to Ostend, to take a look at the scenery and agriculture of Germany and Belgium. A particular observation was the number of small farms which we saw, often with the farm house and steading as part of the small villages we passed through. Often the only thing that distinguished them from other houses was the fact that there was a small tractor sitting outside or a few farm animals. In general though there were very few animals to be seen out in the fields of both Germany and Holland.

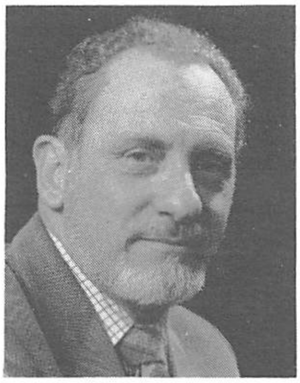
Acknowledgement

I would like to thank the Scottish Branch of the Institution of Agricultural Engineers for the sponsorship they provided, enabling me to participate in this tour.

The man who made a legend

IT was in 1837, the year in which Queen Victoria came to the throne, that a 32-year-old American blacksmith named John Deere set up shop in the small pioneering town of Grand Detour, Illinois, USA.

John Chapman traces the early history of John Deere and the world renowned company he founded.



John Chapman

John Deere arrived in Illinois with his tools and only a few dollars in his pocket. Back in his home state of Vermont, in New England, he had left a pregnant wife, four children and a string of debts. It was make or break time for John Deere.

To begin with, he did what a thousand other smiths must have been doing: he shod horses, he made hand-tools, he repaired wagons and stage-coaches.

The steel plough – the right tool at the right time

Then, one day in 1838, someone asked him to make a plough: and instead of using the traditional wooden or wrought-iron mouldboard, he fashioned his out of steel, salvaged from a broken saw-blade. The new plough was so successful that it marked the beginning of one of the world's largest agricultural machinery firms: one which is still going strong 150 years later, and which for most of its history has been run by John Deere's descendants.

In the 1830's, because of an economic depression, there was a great exodus of people from the 'civilised' eastern states of America into the west – the frontier lands which, at that time, lay only halfway across the country. What confronted the pioneers, as they put up their log cabins, was a huge expanse of open prairie. The land was cheap, but the soil was heavy and sticky, and covered with a dense mat of coarse herbage. Teams of ten pairs of horses or oxen were often needed to break the prairie ground. One of the problems with the traditional wooden or iron plough was that the soil did not scour from the mouldboard, preventing the turning of a clean furrow and greatly increasing the draught of the plough.

John Deere's steel plough could be ground and polished so that the mouldboard was self-scouring. It became known as the 'singing plough', from the ringing sound it made as it sliced through the soil.

The benefits were quickly recognised, and it was not long before John Deere was concentrating most of his energies on plough-manufacture. As the business grew, he started to import special steel from Sheffield, then the steel centre of the world.

Technical capability and flair for marketing

Although he was not the only man, or even the first, to make a steel plough, he was always seeking to make further improvements and modifications and was also better at what is now called marketing, hence his reputation soon spread. After a few years at Grand Detour, he moved his business to the growing town of Moline, on the Mississippi. This offered both river and rail communication as well as water-power and good timber supplies.

Today, 150 years later, Moline is still the headquarters of the John Deere organisation.

As the nineteenth century progressed, and the industrial and agricultural revolutions began to transform traditional ways of farming, John Deere's company grew with it. Steam replaced water and horses in his factories, and he took on more workers. In the early years he entered into various partnerships with other men, but these seldom lasted. Although Deere himself had had little formal education or training in business and finance, he managed by sheer force of personality to ensure that the Deere name remained when these partnerships broke up.

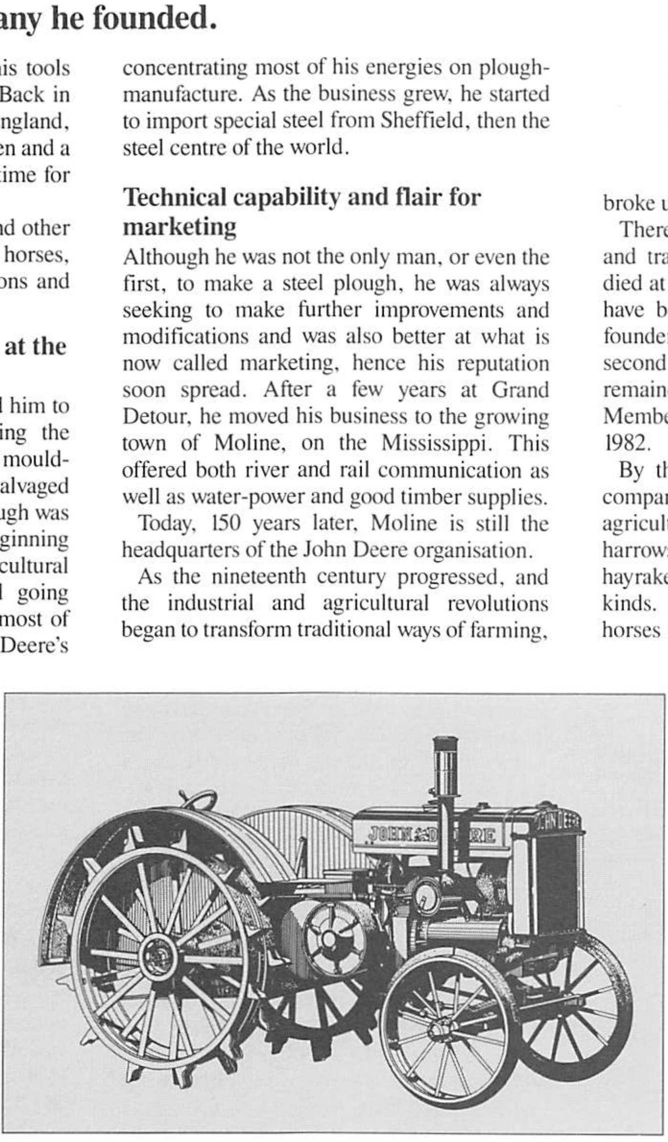


Fig 1. The 'D' tractor was the first Waterloo tractor to bear the John Deere name, and the most venerable, staying in production for 30 years from 1923 to 1953.

There were mistakes and setbacks, of course, and tragedy too: John's eldest son, Francis, died at the age of twenty, just when he should have been entering the business. When the founder himself died, in 1886, it was his second son Charles who ran the firm and remained its chief executive until 1907. Members of the family were in control until 1982.

By the end of the nineteenth century, the company was making a huge range of agricultural implements: cultivators, disc harrows, seed drills, corn and cotton planters, hayrakes, elevators and ploughs of many kinds. A subsidiary built wagons and other horses vehicles such as buggies and surreys. They had even dabbled in the bicycle boom in the 1880s.

Tractor manufacture from 1918

However, it was in 1918 as the First World War drew to a close, that the company took one of its most momentous decisions. With some initial reluctance, it decided to go into the tractor business. That decision led to the name of John Deere becoming synonymous with most aspects of today's power farming, from tractors to combines, from forage harvesters to round balers. It led, too, to the company eventually branching out from its own USA market and becoming international.

A 'green' company for over 100 years

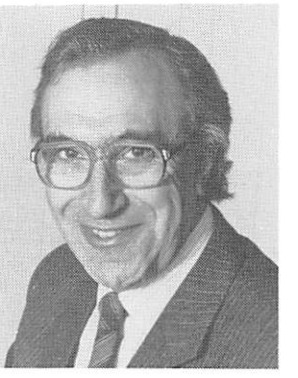
The records do not seem to show exactly when green was first adopted as the John Deere house colour; but a company inventory for 1870 shows a large sum spent on green paint, so the tradition goes back a long way. The 'leaping deer' trademark also seems to date from about that time.

A modern John Deere tractor, a model 3140, is shown in the illustration on page 104.

John Chapman is presently a freelance writer on farming topics, having spent 20 years in agricultural public relations during most of which time he served as PRO for the MMB.

FEANI and the European Engineer

by J C Levy



FEANI The Federation Europeene des Associations Nationales d'Ingenieurs was formed in 1951 to:

- **Secure the recognition of European engineering titles and to protect those titles in order to facilitate the freedom of engineers to move and practise within and outside Europe.**
- **Safeguard and promote the professional interests of engineers.**
- **Foster high standards of education and professional practice and regularly review them.**

FEANI membership is made up of the engineering associations of 20 European countries, including all 12 of the European Community. Each has a Secretary General for FEANI.

The British member body is the British National Committee (BNC) for FEANI, composed of representatives of the Engineering Institutions, the Fellowship of Engineering and The Engineering Council. It is operated under the aegis of the Board for Engineers' Registration. The administration is provided by The Engineering Council and the Secretary General is Professor J C Levy.

The FEANI headquarters consists of a small secretariat located in Paris, headed by the FEANI Secretary General, M Marcel Guerin.

The official languages of FEANI are English, French and German.

The FEANI register of engineers

FEANI introduced its first register of engineers in 1970, entitled 'The Register for the Higher Technical Professions'. In 1987 the earlier Register was replaced by a new one, including the European Engineer title, known simply as 'The FEANI Register'. Registration is in **Group 1** and **Group 2.**

Group 1 is open to engineers having minimum qualifications equivalent to a secondary education validated by certificates awarded at about the age of 18 and either a 4-year university degree or a 3-year degree plus one year of approved engineering training. A certificate of registration is issued to Group 1 registrants who may use it to prove their European credentials when necessary.

Registration in **Group 2** of the FEANI Register is open to engineers with a school certificate awarded at about age 16, plus either a 3-year full-time engineering education or two years' education plus one year of approved engineering training, or a school certificate awarded at 18, plus two years of full-time engineering education. No title is yet awarded to recognise Group 2 registrants with further experience. UK Incorporated Engineers will normally qualify for Group 2 registration.

The European Engineer Title

Engineers having Group 1 qualifications and a further period of professional experience to give a total of seven years from the beginning of their higher education may apply for the title 'European Engineer', abbreviated as 'Eur Ing', recognised by a diploma and a further certificate of registration. The Engineering Council recommends that the title Eur Ing is to be used as a prefix, in front of the name and put before all other ranks and titles. It does not replace the title 'CEng' in this country, which should still be used as a suffix.

Application and Fees

Engineers wishing to register with FEANI should contact the membership department of their own Institution for detailed guidance and application forms. Registration fees are at present £25.00 for Group 1 and Group 2, renewable every five years, plus a once and for all payment of £60.00 for the Eur Ing title.

Income Tax allowance is claimable against the subscriptions to FEANI, which is now on the list of bodies approved for such purposes by the Inland Revenue.

The Register is administered by the National Committees in each of the member countries of FEANI, and by the Paris secretariat. Admissions to the Eur Ing title are examined by a Standing Monitoring Committee formed of experts in the engineering education and training systems of Europe, and then approved by the central Register Commission representing all 20 countries. Applications take several months to go through all these stages and for the diploma to be prepared.

The British National Committee for FEANI is located at 10 Maltravers Street, London WC2R 3ER.

Professor Jack Levy is Secretary General of the BNC for FEANI.

ADVERTISERS INDEX

LETTERS

Europe already a Home Market

Sir, With reference to the Summer edition of the Agricultural Engineer, I would like to comment on the article by Professor J. C. Levy on the subject of the improved European market.

With due respect to the Professor, I believe that the **full** internal market becomes effective from the first of January 1993 and I quote from an EEC Directive.

"Whereas the measures aimed at the gradual establishment of the internal market must be adopted by 31st of December 1992; whereas the internal market consists of an area without internal frontiers within which the free movement of goods, persons, services and capital is guaranteed." That is to state the situation will build up slowly and not suddenly occur in 1992.

Referring to the movement of agricultural machinery which, of course is the interest of the Institution, a little investigation would have shown that there has been, for many years, free movement of agricultural machinery. Of course, there is some irritating paperwork and variations in safety guards, but these problems are now quite minor.

There is no import duty to pay on agricultural machinery although VAT has to be paid at point of entry plus the usual shipping and shipping agents charges. Therefore, Europe is for practical purposes an internal market already for British manufacturers of agricultural machinery.

The article was very interesting and highlighted many points, but could give the small UK company the idea that after 1992 they can easily start trading in Europe, whereas, in fact, they could today be trading with the near European countries.

G E A Rand
Technical Manager
Western Machinery and Equipment Co Ltd
Ivybridge, Devon

Grant data loggers

Grant Instrument's range of 1200 Series Squirrel data loggers features three models designed specifically for environmentally related logging applications.

Guaranteed for three years, they can function unsupervised for several months from internal batteries.

Grant Instruments, Barrington, Cambridge CB2 5QZ. Tel: 0763 60811.

Assessing acid rain

The new Rainwater Conductivity Sensor model 3152 from Aanderaa Instruments of Bergen, Norway, provides an estimate of the acidity of rainfall. Interpreted in conjunction with other data such as the proximity of the sensor to the sea, and the prevailing wind direction, conductivity measurements can suggest whether high readings are due to windborne salt particles or to the presence of pollutants such a NO_2 or SO_2. Such information is important in agriculture, forest management, pollution monitoring (eg for maintenance of masonry, glass and paintwork) and meteorology.

Rainwater is collected by a funnel on the top of the sensor and flows through the sensing element, where an alternating current is passed across the water. The twin carbon electrodes of the sensing element measure the conductivity of the water as the inverse of its AC resistance.

The electronics in the base of the sensor outputs a standard analogue signal. As a result, the unit can be used in monitoring systems together with any Aanderaa sensor scanning or display unit. The Rainwater Conductivity Sensor can also be mounted on the sensor arm of an Aanderaa weather station in the 2700 series, such as the Environmental Station model 2704.

Aanderaa Instruments manufactures a wide range of individual sensors and integral systems for environmental monitoring.

Soil erosion management – new training video

The Overseas Development Unit (ODU) at Hydraulics Research Ltd, Wallingford, has just released a new 24-minute video called 'Soil erosion – a drainage basin approach'.

In preparing the video the Hydraulic Research team has collaborated with the Malawi Ministry of Agriculture to measure rates of soil erosion in various experimental catchment areas. The catchments, around 100 hectares each, were much larger than those usually studied, and therefore more representative of real life erosion problems.

The video shows the research being carried out on four catchments and illustrates the different degrees of soil erosion experienced. On the unmanaged catchment one hundred times more soil was lost than on the fully managed or the forested catchments.

Using techniques and equipment described in the video, the relative benefit of soil conservation methods can be compared and assessed and engineers and development workers will be in a position to suggest beneficial changes.

This new video costs £30 plus VAT and is available from Hydraulics Research Ltd, Wallingford, Oxford OX10 8BA.

Also new from Hydraulics Research is their publication Streamline now to be available to all who use, or may wish to use their services. Streamline contains information about past and present research at Hydraulics Research, the latest techniques derived from that research and the application of those techniques in site-specific project studies.

Tractor clutch manufacture at Rotherham

One of the world's foremost clutch manufacturers has opened a modern new factory in Rotherham.

LuK Lamellen und Kupplungsbau GmbH of Bühl, West Germany was formed in 1965 and has since seen rapid expansion in line with its advanced design and product development programme.

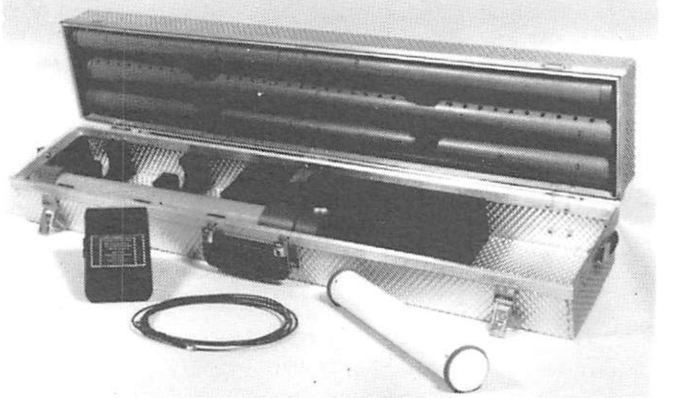
Already the company has over 800 patents to its name and its recent purchase of a specialist electronics development unit confirms the company's innovative approach to automotive and agricultural drive line systems.

The new £15m purpose built LuK factory in Rotherham was officially opened on 5th October 1989 by Trade Minister Lord Trefgarne. This development has now concentrated all LuK's European tractor clutch manufacture on Rotherham and introduced the company's clutch manufacturing operation into the UK for the first time.

Unveiling a plaque to mark the official opening and welcoming LuK's investment in South Yorkshire Lord Trefgarne said: "LuK is one of 70 West German-owned companies from a total of over 300 foreign companies which last year alone recognised the highly attractive business environment in the UK and decided to invest here. "The UK is the preferred location for German, American and Japanese companies investing in Europe and globally it is second only to the USA," said Lord Trefgarne. The Government encourages inward investment and a comprehensive range of services is offered by the DTI to all industry based here.

Financial incentives are also available and the DTI has contributed £1 million Regional Selective Assistance to the new plant, which upgrades the skills of its 170 strong workforce to accommodate the latest technology.

Similar Regional Selective Assistance offered by DTI to companies in South Yorkshire in 1988 has totalled £7.6m towards 81 projects with a total investment value of £85.7m, creating or safeguarding 3660 jobs.



Didcot offer capacitance probe for soil moisture measurement

The Didcot Instrument Company, specialist manufacturer of environmental monitoring instrumentation, has launched a new instrument to measure soil moisture content.

The Didcot capacitance probe works by measuring the soil's dielectric constant; which is proportional to the water content. By taking readings at 2cm intervals to depths of up to 2 metres, the probe produces a soil moisture profile which is both precise and reproducible; and without requiring radioactivity.

The capacitance probe was initially developed and tested by the Institute of Hydrology. It is manufactured under licence by the Didcot Instrument Company.

Dicot Instrument Company Ltd, Unit 14, Thames View Ind. Park, Station Road, Abingdon, Oxford OX14 3UJ.

Refrigerant Recovery by Robinair

Robinair model 1750l Commercial refrigerant recovery and recycling station.

Robinair announce an extension to their increasingly popular range of refrigerant recovery and recycling stations. The latest model, No. 17501 is suitable for the three main refrigerants, R12, R22 and R502.

As with all Robinair models, the design emphasis is on safety and simplicity of operation. There is no need for special skills or operator training, the unit is simply connected to the refrigeration system and switched on. The machine completes the cycle leaving the system under vacuum and switches off automatically.

Each station is supplied complete with 2×50 capacity specially designed recovery tanks. The danger of overfilling is avoided by mounting the recovery tank on a platform which actuates a microswitch and turns off the machine when the tank reaches the limit of capacity. Further protection is afforded by a high pressure cut-off switch and separate relief valve.

The internal compressor is protected by a large capacity filter. Entrained oil is automatically separated during recovery. The station is robustly constructed and mounted on a heavy duty two wheel trolley.

A major advantage of this unit is that the recovered refrigerant may be recycled for subsequent re-use. This procedure is separate to the recovery sequence and again operation is entirely automatic. When convenient, a sequence can be selected to recycle recovered refrigerant through an internal filter and drier. Indicators show when all moisture has been removed and when the filter is clogged.

Independent laboratory tests show that refrigerant recycled by a Robinair station is a higher standard than that orginally supplied. The escalating cost of refrigerant makes recycling increasingly attractive and offsets the unit cost of the equipment.

For further information and a demonstration contact: SPX United Kingdom, Robinair Div., 86 Wharfdale Road, Tyseley, Birmingham Bll 2DD. Tel: 021 707 6955.

Rapid forage analyser from Bran & Luebbe

As a result of a joint development programme between Bran & Luebbe Analysing Technologies and NIR Services, a division of J Bibby Agriculture, a version of Bran & Luebbe's recently launched near infrared analyser, the InfraAlyzer 360F is now available with calibrations which have been specifically developed for forage analysis.

The InfraAlyzer 360F has been designed for ease of operation. Minimal sample preparation is required, and user friendly software means that only minimal training is needed. Using the 360F Bran & Luebbe claim that analysis of fresh grass, hay and silage can be obtained in a fraction of the time needed using comparable wet chemistry techniques.

For example, in less than 5 minutes from the receipt of a silage sample, the InfraAlyzer 360F is capable of analysing for crude protein, ammonia nitrogen, pH, MAD fibre, ash and energy. With this speed of analysis, analysing costs are much reduced, while the ease of operation also means that farmers can now sample from the clamp many times through the season.

When used for analysing fresh grass, the 360F is capable of providing an accurate measurement of protein, moisture, MAD fibre and water soluble carbohydrates. Applied to the analysis of hay, the InfraAlyzer 360F is equipped to provide measurement of crude protein, moisture and MAD fibre levels. The 360F helps to optimise grassland management.

Bran & Luebbe Analyzing Technologies Division, Beechwood, Chineham Business Park, Basingstoke, Hants RG24 0WA. Tel: 0256 842041.

AmbiLog from Neotronics meets COSHH challenge

There is a need to protect workers when entering silos, slurry pits and other confined spaces and when working in environments where hazardous gas concentrations may be found which is underlined by the introduction of COSHH legislation (Control of Substances Hazardous to Health). A new generation of personal gas monitors for assessment of work areas, protection of workers and logging of exposure levels has been developed by Neotronics Ltd.

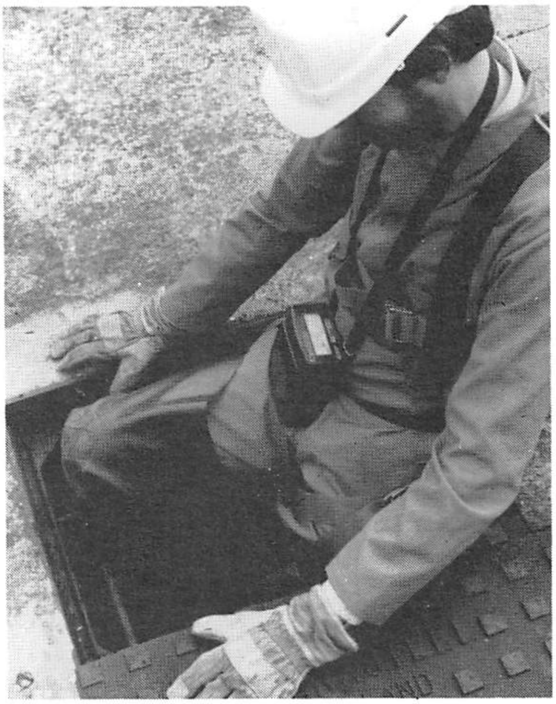
Using a range of miniature sensors, especially developed by Neotronics for this advanced series of gas detectors, Neotronics now offer the first hand held gas monitor to incorporate five gas sensors in addition to temperature and relative humidity measurement.

Oxygen and flammable gas concentration detectors can be incorporated in all models, together with toxic gas options, covering carbon monoxide (CO), hydrogen sulphide (H_2S), sulphur dioxide (SO_2), chlorine (Cl_2) and nitrogen dioxide (NO_2), with alarms at instantaneous, threshold limit and short term exposure limit values.

A large 23 × 74mm dot matrix display can be configured to give either simple user warnings and alarm information, or full display of all measured parameters and calculated exposure levels. In addition, a peak hold facility gives the maximum and minimum readings during the monitoring session and a comprehensive set of alpha-numeric help instructions, available in a number of alternative languages, is also provided.

All of the enhanced features of the new EXOTOX monitor range are packaged in a lightweight (750 gram) compact (80mm × 110mm × 160mm) high impact strength moulded case with an optional carrying case. The EXOTOX can be belt or body harness worn and incorporates many more functions than other substantially larger instruments currently available.

Further information: Neotronics Limited, Parsonage Road, Takeley, Bishop's Stortford, Herts, CM22 6PU. Tel: 0279 870182.



Exotox 60 Atmosphere Monitor in use for confined space entry.