THE AGRICULTURAL ENGINEER

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Volume 30 Winter 1975 No4

THE INSTITUTION OF AGRICULTURAL ENGINEERS

Presidential Address and Annual Conference

Tuesday, 11 May 1976.
at the Bloomsbury Centre Hotel, London.

10 20—11 00	Presidential Address — Research in Agricultural Engineering T C D Manby BSc MScEng CEng FIMechE FIAgrE

Annual Conference

Engineering Developments in Forage and Grain Conservation

11 00—11 25	Coffee
11 30—11 35	C Culpin OBE MA DipAg (Cantab) FIAgrE Conference Chairman — Opens the Conference and Sets the Scene.
Morning Session	
11 35—11 40	Session Chairman, R W Waltham (President, British Grassland Society)*
11 40—12 15	Paper 1 Methods of harvesting and conserving silage and hay in the Netherlands. Ir G A Benders, Instituut voor Mechanisatie, Arbeid en Gebouwen, Netherlands.
12 15—12 30	Discussion on Paper 1.
12 30—14 15	Annual Luncheon.
Afternoon Session	
14 25—14 30	Session Chairman, C Culpin.
14 30—15 00	Paper 2 The field treatment of grass for conservation. W E Klinner FIAgrE Mem ASAE National Institute of Agricultural Engineering, Silsoe, Bedford.
15 00—15 10	Discussion on Paper 2.
15 10—15 40	Paper 3 Drying of hay and grain. M E Nellist PhD MSc (Agr Eng) MIAgrE National Institute of Agricultural Engineering, Silsoe, Bedford.
15 40—15 50	Discussion on Paper 3.
15 50—16 10	Tea.
16 15—16 45	Paper 4 Conservation and feeding of forage crops. W F Raymond MA FRIC, Deputy Chief Scientist, Ministry of Agriculture, Fisheries and Food, London.
16 45—17 00	Discussion on Paper 4.
17 00—17 40	Open Forum — Conference Chairman, Morning Session Chairman and all Speakers. Discussion to be opened by: P H Bailey BSc (Eng) MSc (Agr Eng) AKC FIAgrE Scottish Institute of Agricultural Engineering, Penicuik, Scotland.
17 40—17 45	Summing-up and Closure by Conference Chairman.

Conference Convenor: G Shepperson BSc (Agric) FIAgrE
National Institute of Agricultural Engineering, Wrest Park, Silsoe, Bedford.
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**The Conference is being held in Association with the British Grassland Society.*

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Cover: Tractor fitted with NIAE experimental suspended cab.

The future for operator efficiency and safety in the agricultural industry

by Theo Sherwen and Colin Brutey

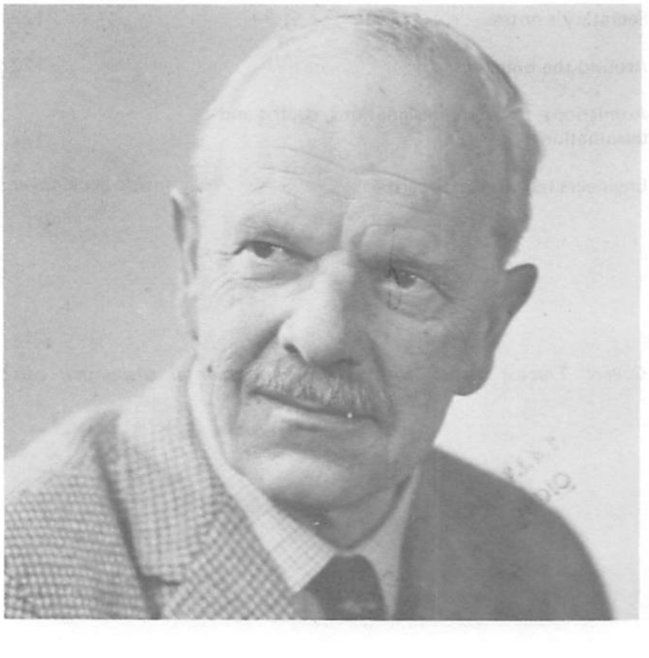
THE year 1975 has been one of great significance in the sphere of farm safety. It has, of course, been National Farm Safety Year. It has seen the coming into full effect of the Health & Safety at Work Etc Act. It has seen the coming of the first "quiet" cabs on popular model tractors. Above all it has seen a marked reduction in the fatalities on our farms. Furthermore, it has seen a change in attitude to safety. Despite the extension of legislation, of even greater importance has been the change in attitude of mind towards the subject. Would we have had over 130 people at a safety conference a few years ago, as we had at the National Agricultural Centre in October?

What are the implications of this to the Institution? As John Weeks, Director of Farm Safety at the Ministry pointed out in the opening paper of the Conference, the new Act places quite specific responsibilities on designers, manufacturers and suppliers of farm machinery. What is of even greater import is that this responsibility is imposed in such a way as to exercise the judgement and expertise of the designer and manufacturer. Undoubtedly new demands will be made upon the agricultural engineer; demands that will be reflected in calls upon our Institution to ensure that the agricultural engineers of the future have had the right training, are of the right calibre and have acquired the necessary experience to meet the requirements of the Act, which calls for expertise and foresight in new project engineering over and above the demands for more efficient mechanisation imposed by the economic pressures on the farming community. What is more, as Ron Easterby of the University of Aston in Birmingham emphasised in his paper, it will no longer suffice to cater for the purely physical aspects of the safety and well-being of the operator. At last we have awakened to the realisation that farmers and their men who drive and operate machines have minds, sensitivities, and feelings over and above those of animal comfort. The operator of the modern, huge, fast moving machines must apply great judgement and discernment to his task. To do so in such a way as to secure a profitable rate of work he must be aided by a control layout whose proper use is instinctive without training, whose instrumentation is designed and laid out so that it can be monitored at a glance. Furthermore the seating position must allow operation all day in comfort with full visibility of the work performed. Operator safety and efficiency is no longer simply a matter of preventing him from cutting his fingers off!

Nor is this development in the responsibilities of agricultural engineers confined to those in the realm of Chartered Engineer or Technician Engineer. The farm machinery repair trade is, perhaps in some cases unwittingly, on the brink of revolution. Quite apart from added responsibilities imposed upon them by the new Act, economic pressures upon dealer and farmer alike are bound to change the pattern of repair procedures on the farm. The higher rate of pay imposed upon dealers will in due course result in the dealers staff handling only the complex work requiring specialised tools and the simpler repairs and maintenance being done by farm staff. These pressures will necessitate the raising and strengthening of the level of technical qualification in the service industry, and it must be recognised by government services as well as private industry that competent service to agriculture can only be given if the personnel framework of the industry is properly qualified at all levels from Chartered Engineer down.

A study of the papers presented at this Conference will show that this situation will present a challenge to the Institution in so many spheres of activity. Not least we must exert our authority in making clear to the world at large and to the engineering profession in particular, the status of the agricultural engineer. We must make it clear to the education and registration authorities that agricultural engineering needs a particular blend of agricultural and engineering knowledge and experience to produce the properly qualified agricultural engineer. This specialised background knowledge of the industry which we serve will become of even greater significance in meeting the responsibilities placed by the Health & Safety at Work Etc Act upon agricultural engineers, be they designers, manufacturers, installers or repairers of farm machinery.

Theo Sherwen



Colin Brutey

The Health and Safety at Work Etc Act 1974: Its effect on designers, manufacturers, suppliers and installers of agricultural machinery

by J C Weeks FIAgrE

Summary

THE main provisions of the Health and Safety at Work Etc Act 1974 are described and some guidance given in respect of the general duty obligations of designers, manufacturers, importers, suppliers and installers contained in Section 6 of the Act.

The changes made by the Ministry of Agriculture, Fisheries and Food to discharge their additional and very much wider responsibilities are explained. These include the restructuring and strengthening of the inspectorate and the setting up of the Farm Safety Steering Group.

The paper points out that only a Court can give an authoritative interpretation of the Act and its regulations.

1 Introduction

THE Health and Safety at Work Etc Act 1974 reflects many of the recommendations contained in the Report of the Committee of Enquiry on Safety and Health at Work – chaired by Lord Robens – published in 1972. This new legislation provides, for the first time, an integrated system of law dealing with the health and safety of virtually everyone at work including those engaged in education, research, medicine etc and members of the public where they may be affected by work activities. Thus employers, the self employed and workers (except domestic servants in private households) are covered by the Act. Its purpose is to provide a framework to promote, stimulate and encourage a high standard of health and safety at work and calls for a new concept of consultation, participation and co-operation between employer and worker.

Existing regulations including those under the Agriculture (Safety Health and Welfare Provisions) Act 1956 remain in force until revoked and replaced by improved and updated regulations and codes of practice made under the new Act. Regulations made under the Agriculture (Poisonous Substances) Act 1952 for the safe use of pesticides have already been replaced by the Health and Safety (Agriculture) (Poisonous Substances) Regulations 1975 under the 1974 Act.

2 Enforcement

The Health and Safety Executive was set up on 1 January 1975 as the operating arm of the Health and Safety Commission and, except for agriculture, is responsible for enforcing the requirements of the Act and existing regulations. At the same time the inspectorates for factories, mines and quarries, explosives, nuclear installations and alkali works and Safety in Mines Research Establishment were transferred to the new Executive. In agriculture the farm safety inspectorate has been restructured and strengthened to fulfil the Minister's new and wider responsibilities for health and safety under the 1974 Act. The Act extends the powers of inspectors to include the issue of prohibition and improvement notices and offences and any penalties imposed are now dealt with under the provisions of the new Act.

J C Weeks is Director of Farm Safety, Ministry of Agriculture, Fisheries and Food.

Paper presented at the Autumn Conference of The Institution of Agricultural Engineers, held in The Conference Hall, National Agricultural Centre, Stoneleigh, Warwickshire, on 14 October 1975.

3 General duty obligations for employer, self employed and employee sections 2-5 and 7

These general duties are fundamental to the Act and some of the more important include:–

3.1 Employer – to ensure as far as is reasonably practicable the health, safety and welfare at work of his employees and of other persons affected by their work activities.

3.2 Self Employed – to conduct his undertaking so as to ensure as far as is reasonably practicable that he and other persons – not being his employees – who may be affected are not exposed to risks to their health or safety.

3.3 Employee – to take reasonable care for the health and safety of himself and of other persons who may be affected by his acts or omissions at work.

4 General duties of designers, manufacturers, importers, suppliers and installers regarding articles and substances for use at work section 6

These duties are extensive and it would seem helpful to discuss them in more detail. They apply only to things done by a person in the course of a trade, business or other undertaking carried on by him.

4.1 General – Sections 6(1) and (2) require a designer, manufacturer etc to ensure, as regards matters within his control, that so far as is reasonably practicable, any article (ie machinery, equipment, appliance, component etc) or substance he designs, manufactures, imports, supplies or installs is safe and without risk when properly used. To comply with this duty manufacturers are obliged to carry out such testing and examination as may be necessary. They must also do whatever is reasonably practicable to ensure that information is made available about the use of the product, and about precautionary measures indicated by such tests. Designers and manufacturers of machines etc and manufacturers of substances are also required to carry out necessary research, with a

→ *page 92*

view to discovering and, so far as is reasonably practicable, eliminating or minimising risks to health or safety. However any testing, examination or research already done by others need not be repeated if it is reasonable to rely on the results. Provision is also made for relieving designers, manufacturers, importers and suppliers of their general duty when the person for whom the machine is designed gives a written undertaking that he will take the specified steps sufficient to ensure, so far as is reasonably practicable, that the machine is without risk to health when properly used.

4.1.1 Intention — the purpose of these sections of the Act is to lay duties on all those who are involved in the chain of supplying machinery and substances for use at work, to ensure generally that the products are and continue to be safe when put to their intended use and in particular that any health and safety requirements relating to them are complied with before they come to the point of use. Thus the aim is to get safety design built into the products, rather than placing the full onus of ensuring the goods are safe to use on the employer or other responsible person eg the self employed, owner of premises etc. This approach is considered to be more equitable and comprehensive and is aimed at producing more satisfactory technical solutions to safety and health problems. Hence the obligations relating to research, testing and inspection. Designers and manufacturers are under an obligation to include health and safety among factors which they take into account when producing and marketing goods rather than leaving it to the responsibility of others.

4.2 Testing and examinations

Testing and examination is required to be undertaken as necessary in support of the broad general duty of ensuring the safety of machines etc.

4.2.1 Intention — to cover prototype testing of designs in addition to quality control testing and examination of the finished product, and is basic to the idea of securing built-in safety wherever possible.

Importers also have this duty since it cannot be imposed on designers and manufacturers in other countries. It would be wrong for imported goods to be subject to less stringent safety conditions than home produced ones or for foreign manufacturers to be allowed to gain competition advantage in terms of cost savings on safety. The responsibility is that of the importer to ensure that the overseas manufacturer has done the equivalent of what is required of the British manufacturer and if not to arrange for testing and examination in this country before he supplies the goods.

A supplier would not normally need to do any testing or examination since this should have been done by the manufacturer or importer. But where a supplier deals with secondhand goods which may require maintenance or repair, or undertakes certain modifications to a machine eg for a particular market, he will need to take steps to ensure that it is still safe to use and that the repair or modification does not affect the safety of the article.

4.3 Supplying information

Those involved in the supply chain are obliged to make available to users information of the uses for which machines etc have been designed and tested and found to be safe and the conditions for their safe use. The way in which information is made available will of course depend upon circumstances — it may be in the form of labelling eg of a container or may be more comprehensive instructions and advice such as in operator manuals etc. Whatever the form of the information the supplier must ensure that it is passed on to the buyer.

4.4 Research

Designers and manufacturers of machines etc for use at work have a duty to carry out or arrange for the carrying out of any necessary research with a view to the discovery and, so far as is reasonably practicable, the elimination or minimisation of any risks to health or safety to which the design may give rise.

4.4.1 Intention — the obligation goes beyond carrying out tests on articles intended for a particular use to check upon their safety for that use as described in para 4.2. The aim is to stimulate designers and manufacturers to carry out research with a view to producing alternative designs or models, with the positive intention of producing products which are as safe as possible. The product design policy of overseas designers and manufacturers clearly cannot be controlled in this way and so no duties are laid upon importers to conduct research. This may appear to put British manufacturers at a disadvantage but a safe product is a better product and should therefore be more competitive. Similarly the extent to which suppliers can influence the safety of products which they handle is limited by what has been done earlier in the chain of supply and the duty would not therefore be appropriate to them.

4.5 Erecting or installing

Section 6(3) requires those who erect or install machinery and appliances etc for use by persons at work to ensure that as far as is reasonably practicable nothing in the way in which they are erected or installed will render them unsafe or a risk to health when properly used.

4.5.1 Intention — this is a logical follow through of the general duties of those in the supply chain. Erection and installation including assembly on the premises can be very specialised work, particularly important in ensuring continuing safety, and is frequently not done by the manufacturer or supplier. Guards must be correctly fitted, machines properly anchored and perhaps positioned so that the moving parts are not exposed, and dust or fume extraction equipment and noise suppression equipment may have to be fitted in certain circumstances and so on.

4.6 Substances — manufacturers, importers and suppliers

Section 6(4) places similar duties on manufacturers, importers and suppliers of substances for use at work to those placed on designers, manufacturers, importers and suppliers of machines etc. The obligations are not intended to cover consumer protection or household use but only the industrial uses of all substances.

4.6.1 Intention — while the requirements are similar to those in relation to machines for obvious reasons no obligation is placed on designers and the requirement to provide information is intended to refer to the results of any relevant tests and research carried out on or in connection with a particular substance.

4.7 Re-testing

Section 6(6) of the Act provides that a person should not be required to repeat a test, examination or research which was not carried out by him, or on his instructions, insofar as it is reasonable for him to rely on the results obtained by others.

4.7.1 Intention — the aim here is to avoid the need for any duplication of research etc. A decision whether it is reasonable to rely on results obtained by others will depend on circumstances and the manufacturer will have to consider the relevance of the tests, how well they were carried out, the methodology used, their reliability etc.

4.8 Written undertakings

Paragraph 8 of Section 6 makes it clear that when someone gives a written undertaking that he will take specified steps to ensure so far as is reasonably practicable that an article passed to him in the chain of supply will be safe and without risks to health when properly used, then the designer, manufacturer, importer or supplier passing it to him is relieved of his duties in respect of the article to the extent that the terms of the undertaking makes reasonable.

4.8.1 Intention — this will enable customers to order plant made to their own specifications, or to order unfinished machinery eg with the intention of fitting special guards supplied by another manufacturer, without putting designers, manufacturers etc at risk for failing to comply with their duties. It also enables a manufacturer to supply to another manufacturer an article which is meant to be used as a component in a larger installation but is capable of independent use, even though the article is in an unsafe condition as it stands.

4.9 **Credit sales**

Section 6(9) makes special provision for certain cases where a machine or substance for use at work is supplied to a person under a hire purchase agreement, condition of sale agreement or credit sale agreement. In this situation there may be two "suppliers" — the credit company and the dealer. The Act ensures that the responsibilities for safe use etc fall on the supplier of the machine rather than the money — the credit company — since the former will have any safety matters within his control.

4.10 **Properly used**

Paragraph 10 of Section 6 provides that an article or substance is not to be regarded as properly used when it is used without consideration of any relevant information or advice which has been made available by its designer, manufacturer, importer or supplier.

4.10.1 Intention — this recognises that it would not be reasonable to require the duties imposed on designers, manufacturers, importers and suppliers of articles and substances to relate to *all* uses to which an article or substance may be put. Duties are therefore confined to "proper use" and whether a machine etc was properly used will be a matter for the Courts to decide on the facts of a particular case. An example of when these bound by the duties might not be held responsible would be where the relevant available information or advice had been ignored.

5 The role of the safety inspectorate

The concept to place responsibilities on manufacturers and dealers etc to ensure that when they supply a new machine it should comply with regulations is not new in agriculture. Indeed it was embodied in the Agriculture (Field Machinery) Regulations 1962 and later in the Agriculture (Tractor Cabs) Regulations 1967 which have since been amended and revised to a 1974 edition. Over many years the inspectorate has built up a close liaison with manufacturers and advised them on the requirements of the regulations and health and safety matters in general. I am very appreciative of the co-operation the inspectorate has received from manufacturers and dealers. This has been of immense value and assistance in our joint efforts to improve the standard of guarding and safety devices provided on tractors and machinery sold for use on our farms. Equally commendable and appreciated is the part played by manufacturers of pesticides and other toxic substances to ensure the continuing success of the Pesticides Safety Precautions Scheme so maintaining the remarkable record of safe use of pesticides in agriculture.

But it will readily be recognised that the 1974 Act goes much further than any previous legislation and the increased and wider responsibilities will demand greater attention and involvement than ever before from those concerned with manufacture and supply. In order to provide the industry with the maximum assistance to meet these new responsibilities the existing procedure for inspectors to visit and advise manufacturers have been changed. Whereas regional safety inspectors have always dealt with manufacturers as part of their overall duties five additional inspectors have been appointed to specialise in health and safety in respect of machinery, buildings etc and to advise manufacturers, importers and suppliers on their obligations under the Act. These principal safety inspectors will be stationed in London, Bristol, Wolverhampton, Nottingham and Cambridge and will cover the whole of England and Wales.

6 Farm safety steering group

In addition to restructuring the inspectorate the Minister of Agriculture, in order that agriculture and its allied industries can play a full part in his new farm safety regime, has set up a special steering group to advise him on the scope, provisions and priorities for health and safety in agriculture in England and Wales and to keep departmental measures and progress under review. The group is chaired by the Parliamentary Secretary Dr Gavin Strang and comprises representatives of employers and workers and of all relevant organisations and interests within the industry. The group has had four meetings so far and has already made a substantial contribution to the progress in agriculture since the Act became law, advice for new regulations and Codes of Practice ranging over a wide field including poisonous substances, 3-point linkage mounted equipment, slurry pits, safe handling of bulls and narrow tractors.

7 Conclusion

The Health and Safety at Work Etc Act 1974 is unique in that it provides the most comprehensive coverage ever for the protection of those at work and for the public who may be affected by work activities. Obligations and responsibilities affect a wide field and this paper concentrates on those likely to be of most interest and relevance to delegates to this Conference ie designers, manufacturers, importers, advisers and those engaged in research etc. When advising on legislation it is always necessary to point out that the interpretation of any Act and its regulations is a matter for the Courts. Any explanation given here is intended for guidance only and does not purport to be an authoritative interpretation of the Act. Manufacturers and all concerned in the chain engaged in supplying machines and substances etc for use in agriculture are strongly advised to consult their own legal advisers should they require information on any aspect of this legislation.

Reprint Service

CHANGES have recently been introduced in the reprint service offered to members of the Institution. The Editorial Panel has now made arrangements with University Microfilms Limited, St. John's Road, Tylers Green, High Wycombe, Bucks., for *The AGRICULTURAL ENGINEER* to be placed on microfilm from which enlarged copies of articles or papers can be obtained. Those members wishing to obtain copies of articles should now address their requests direct to University Microfilms Limited who will make a charge for this service at the rate of $3 each for articles and 8c. per page for complete issues. Charges will of course be made in sterling, the equivalent being obtained by conversion at the rate current at the time of placing order.

University Microfilms Limited have now been supplied with earlier volumes of the journal and it is hoped that in future members' requirements can be met by this service.

Design considerations for the effective guarding of mowing machines

by W E Klinner FIAgrE MemASAE

1 Introduction

THE size and trajectory of objects, particularly stones, which can be projected by rotary mower knives, by flail mower or harvester flails, or by other crop engaging components are largely a function of the kinetic energy of the component and the angle and point of contact with an object. Quite complex situations can arise because the possibility exists of multiple impacts and subsequent ricochetting, and the crop engaging components themselves can fail or, exceptionally, become detached. In the context of human safety the size of a projected object is unimportant, since even a small splinter can cause the loss of any eye, or worse if it were to penetrate the skull or chest.

During research and development with mowers and conditioners at the National Institute of Agricultural Engineering[1,2] it was sometimes necessary for personnel to make observations and measurements in proximity of the machines. To protect operators and attendant staff, a high standard of guarding was essential. Some of the improvements introduced to achieve this objective may be of more general interest.

2 The problem

Cutting crops by impact involves much higher knife speeds, and therefore a greater risk factor, than cutting by single or double shear, as with reciprocating mowers. The following table illustrates some of the characteristic differences between machine types.

Table 1 Examples of critical mower data

Machine type	*approx. mass of cutting component* *kg*	*mean effective cutting speed* *m/s*
reciprocating mower		
single knife	3.650	2.4
double knife	3.280	3.8
rotary mower		
4-disc	0.160	77
4-drum	0.075	71
2-drum (a)	0.080	74
(b)	0.080	77
(c)	0.070	84
disc mower conditioner	0.175	74
flail mower (a)	1.720	36
(b)	1.850	31–46
(c)	1.180	37
flail forage harvester (a)	1.720	44
(b)	1.850	52
(c)	1.180	50
double-chop forage harvester (a)	1.000	47
(b)	1.010	53
flail verge mower	0.135	40
rotary slasher	2.560	66

W E Klinner is from the National Institute of Agricultural Engineering, Wrest Park, Silsoe, Bedford.

Paper presented at the Autumn Conference of The Institution of Agricultural Engineers, held in The Conference Hall, National Agricultural Centre, Stoneleigh, Warwickshire, on 14 October 1975.

For each type of mower there are likely to exist distinct zones in which the risk of injury from projected stones is particularly great. A study has been made of two-drum mowers, and fig 1 illustrates the danger zones which have been broadly defined by observation and the use of pvc-covered frames to record the passage of airborne stones. The mower shown is guarded in conformity with the minimum statutory requirements[3] by a top cover with metal frame which extends horizontally 300 mm beyond the knife tips on all sides.

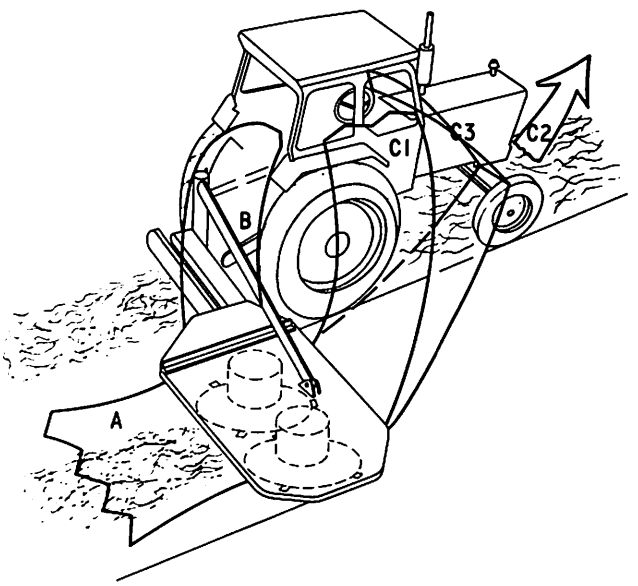


Fig 1 Major high-risk zones around a rear-mounted two-drum mower fitted with top cover in compliance with current statutory requirements.

First contact with stones is made by rotary mowers in front of the transverse axes of the cutting discs. Some stones may be 'scooped up' and can be ejected to the rear, Zone A in fig 1, where they constitute a hazard largely to bystanders. Stones in Zone B start by being projected sideways and then rise into the tractor cab space probably as a result of ricochetting off the left hand rear wheel, drawbar assembly or other tractor component. In Zones C1-3 stones have usually been 'undercut' by the knives. If this causes them to rise towards the tractor steeply, they can enter the cab space from the side, Zone C1; if the resultant trajectory is more shallow, they threaten bystanders ahead of the tractor, Zone C2, or sometimes they are deflected back towards the cab off the tractor front wheel and axle, Zone C3. Because of the presence of uncut crop, stones projected forward at a low level or away from the tractor do not normally constitute as great a danger, but they had to be considered in the context of research and development.

Conclusive evidence was found that, on breaking, some rotary mower blades are deflected steeply upwards and are then capable of penetrating the re-inforced plastic material often used as top covers. In this application the plastic material is almost invariably tightly stretched, to enhance appearance and prevent the accumulation of crop. As a result it is relatively easily punctured by sharp objects.

Fig 2 shows a pvc-covered indicator frame in position behind the

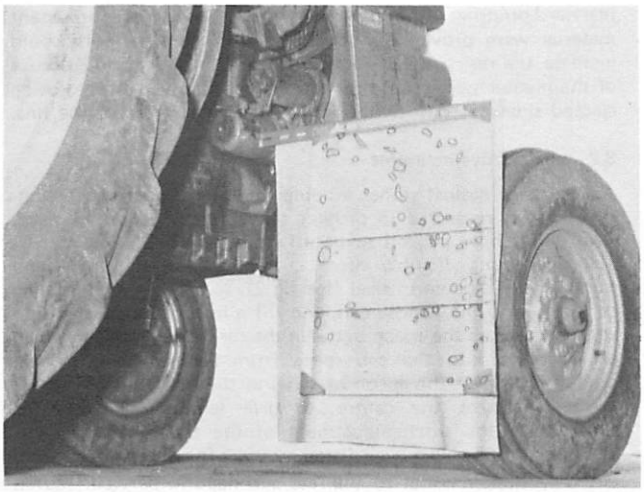


Fig 2 A pvc covered frame for identifying the passage of airborne-stones; it is used here to verify the effectiveness of a protective curtain behind the tractor front wheel.

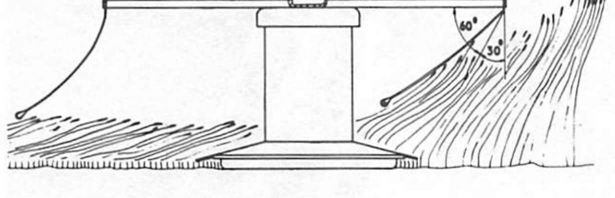
right-hand tractor front wheel. Holes in the plastic film caused by stones have been ringed to make them easily visible. Some of the stones which have impinged in and just around the marked horizontal zone have had the potential of being deflected back into the cab space.

With disc mowers the high-risk zones are probably similar to those of drum mowers. With most flail mowers there would seem to be little or no risk at the rear and sides, but at the front the need for guarding is particularly great. In mower-conditioners objects can be projected also by the conditioning rolls or rotors; sometimes interaction between the mowing or feed mechanisms and the conditioning device increases the hazard.

Responsible manufacturers of rotary mowers have already provided vertical check curtains around their machines, although present legislation does not require these; the curtains are usually suspended loosely from the statutory guard rail so that the material is able to yield on impact and projected objects are checked and rendered harmless. Fig 3, which again relates to a drum mower, shows how effective vertical curtains are to the rear where the outflowing crop deflects them away from the knives and forms the seal with the ground at the bottom. However, at the front the uncut crop forces the curtain towards the mower knives so that they become exposed to the operator's view when the deflected angle is only about 30°.

Hence, stones can rise from the front of the cutting circles and this enables them again to reach the cab space from the side. The small amount of crop which is sufficient to deflect the curtain,

Fig 3 Effectiveness of stone arresting curtains fitted 300 mm behind and in front of the cutting discs and 600 mm above ground.



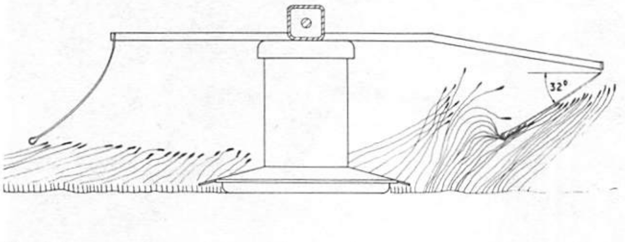


Fig 4 Increased effectiveness from a deeper crop barrier and lower exit angle obtained by moving the front curtain forward to 700 mm ahead of the cutting discs and lowering it to 450 mm.

sometimes well over the cutting discs, is a relatively weak barrier and therefore has a poor damping effect. If the check curtain is suspended from a shorter distance ahead of the knives, as is the case with some mowers at present, even less favourable conditions prevail. At the sides the check curtains, where fitted, are also easily deflected to expose the knives.

With disc mowers the situation is basically similar, provided the height of the suspension rail for the check curtain is the same. With flail mowers more elaborate steps have been taken by some manufacturers. Many of these measures seem quite effective but they include the fitting of transverse banks of pivoted metal flaps; unfortunately these are often too short and gaps between adjacent flaps can be caused by differential deflection, so that a route into the cab space can open up momentarily on occasions. At NIAE an additional flexible curtain forward of such flaps is considered to be an essential precaution.

3 Preventive and protective guarding

The ideal guarding arrangement should give complete protection to by-standers and operators alike, without impairing machine performance or restricting access for maintenance and repair. Preferably it should be simple and compact, but composite solutions involving the best practicable design of mower guard combined with protective devices on the tractor can be acceptable and may be easier to achieve.

3.1 Preventive measures

The ,most effective form of guarding is that which prevents objects from being launched into dangerous trajectories. The effectiveness of vertical check curtains of resilient material suspended from guard rails at least 300 mm behind the cutting circles of the knives has already been discussed. Whilst for normal circumstances this arrangement seems to be adequate, it is a general principle that the greater the horizontal distance between the cutting knives and the check curtain, the lower will be the trajectory of any object which escapes and the greater is the protection afforded by the curtain if the mower has to be reversed, perhaps to clear a blockage. Other essential features are adequate length, weight and flexibility of the curtain to form an effective seal at the bottom.

At both sides of the mower a similar relationship between the knives and check curtain has been found to give good protection, provided it can be maintained. To prevent the crop deflecting the curtain towards the knives, one or more rearwardly slanting metal stays attached to the guard rail or top cover and extending to within 150-200 mm of the ground have proved to be effective and have the advantage that they do not collect crop which can cause stretching and lifting of the curtain.

The biggest problem area with rotary and flail mowers exists at the front where the risk factor is greatest and the crop must be kept in a favourable condition for efficient cutting. NIAE trials with single and double check curtains at varying heights and distances ahead of the mower knives have led to the configuration sketched in fig 4. The curtain is 450 mm deep and fixed the same distance above ground and slightly more than one and a half times this distance, ie 700 mm, horizontally in front of the cutting circles. If it were deflected into a straight line with the knives, it would make a theoretical angle of 32° with the ground. A relatively large quantity of crop is trapped under the top front cover and held down by the curtain, although some is able to rear up again slightly prior to being cut. Thus a good seal and dense barrier is created which leaves stones little chance to penetrate, and the inclination of the crop is not too unfavourable at the point of cutting. The lower the top cover and suspension rail for the curtains at the front, the fewer stones can escape forwardly and, again, the lower are the trajectories of those which do. However, with front ground clearances of appreciably less than 450 mm it was feared that crop flow might be seriously impaired with some mowers in very long grass.

To hold the check curtains down effectively, a light chain inserted into the bottom seam has been found to be satisfactory. A disadvantage of this is that with several materials currently in use it accelerates wear along the lower edge. An alternative, tough, wear-resistant material which is now being offered for mower guards is smooth, semi-rigid plastic sheeting said to be specially formulated for the purpose. At approximately 1.4 mm

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thick it may be suitable for replacing the more conventional check curtains. Being quite stiff it could be fitted in such a way that deflection by crop pressure is counteracted to some degree. Because in made-up form it would be lighter, with more favourable frictional properties than a weighted flexible curtain, it may enable the vertical clearance under the front top cover to be reduced nearer to 300 mm or even less. One aspect needing investigation is whether or not an adequate seal can be effected at the bottom.

To arrest broken mower blades, NIAE experimental machines have been given top covers of metal sheeting. Provided these are carefully fitted, noise and vibration need not be objectionable. A possible alternative again is semi-rigid plastic sheeting; a suitable thickness to give complete protection would need to be determined.

In fig 5 the experimentally guarded semi-mounted NIAE prototype drum-mower-conditioner is shown in the working position. Because of the forward action of the conditioning rotor, its position relative to the cutting discs and the presence at the rear of a stripping rotor with full-width rubber paddles, no low-level guarding in the centre section at the rear has been necessary. The deep horizontal baffle plate at the top of the rotor housing is entirely effective and often bears the marks of stone impacts near the hinge point. Fig 6 shows the machine in transport position with the front portion of the extended top cover folded up to reduce width. This arrangement also enables easy access to be gained to the discs and knives for checking and servicing. An essential feature of the hinged front cover is a friction lock which holds it safely in the raised position. Because of the folding arrangement the check curtain has to be in two parts at the sides; swivel-head fasteners ensure secure fixing and continuity of the curtain in work. An alternative to a pivoted top cover extension at the front is one which slides horizontally into the work and transport positions. It has also been tried successfully but does not give the same ease of access and is subject to misuse.

More substantially constructed versions of the front guarding arrangement developed at NIAE for rotary mowers could be appropriate to flail mowers and harvesters. The effectiveness of multiple metal flap guards might be improved if integral, rearward-pointing fins of radial form and impact-resistant material were provided at the sides of each flap; this would increase the resistance of individual flaps to deflection, because of the greater weight, and reduce the possibility of stones being ejected sideways due to the lateral covering effect of the fins.

3.2 Protective measures

As insurance against stones evading the mower guards occasionally, special measures to protect the operator can be devised. Two which have proved to be effective in NIAE work are: (i) a loosely hung, flexible check curtain behind the right-hand tractor front axle and wheel (see fig 2), to prevent stones being deflected into the windscreen, and (ii) a horizontal check apron stretched across the space between the rear mudguards, to block off entrance into the cab space from behind. Each of two support stays for the apron material at the sides can be readily pivoted towards the centre, to give temporary access for example to the pitch adjustment of the tractor lift linkage. Vertical curtains have been fitted by users for the same purpose, but they impair vision to the rear and need to be well secured behind the seat.

Finally, the possibility exists of totally protecting the tractor driver in his cab by providing transparent, shatter-proof screens at the front, rear and mower side. Laminated and reinforced safety glass is expensive, heavy and not entirely break-proof. More recently clear polycarbonate sheeting has become available which is so highly impact resistant that it can be described as bullet-proof. Additional advantages are that it is only half the weight of glass and weather-stabilised. With so many favourable properties this material will almost certainly find many applications in the field of operator protection.

3.3 Position of mower

As far as the operator is concerned many of the safety problems stem from the offset position of the mower relative to the tractor. Alternatives to offsetting which would reduce the problems are to place the machine in-line behind or in front of the tractor. The former approach is used with some flail mowers, but because the tractor wheels precede the mower, the crop is not always cut efficiently in the wheel tracks, and in some

Fig 5 NIAE experimental mower-conditioner with improved guarding.

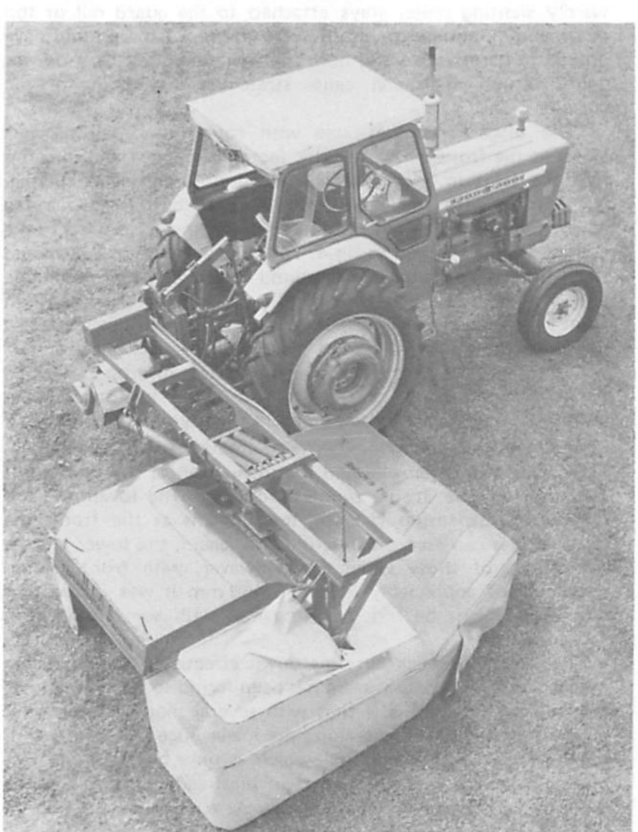

Fig 6 NIAE experimental mower-conditioner in transport position with extended front cover raised and locked.

crops, particularly those destined for seed, the damage caused by the wheels would be unacceptable whatever the type of mower. Front mounting should give improved manoeuvrability and weight distribution, particularly on slopes, and better control and supervision of the mowing operation; all these aspects have safety implications. Additionally, the driver is subject only to low risk from projected objects and can be easily protected. At present only expensive special tractors offer the possibility of front mounting of mowers.

With most conventional tractors the main difficulty is the absence of a front power take-off, but one major manufacturer has started to market optional front lift facilities and an electro-magnetically engaged front pto.

4 General design points

Plant juices can be very corrosive and, therefore, dead corners and crevices have been avoided as much as possible in metal parts for NIAE guards. The wider use of suitable plastics could minimise existing problems of corrosion, fatigue, wear and tear, and promote lightness of construction. Damage through physical contact, for example with tractor wheels during lifting or turning, must be avoided by providing adequate zones of clearance. Maintaining the functional effectiveness of guards is important and needs to be considered at the design stage; it can be facilitated by the use of durable fastening devices. Shatter-proof transparent guards which stay sufficiently clean to allow the operator to observe crop flow would be ideal for grass mowers. If the speed of impact cutters could be reduced, as seems likely, it would also reduce the risk factor.

Different considerations need to be applied to the design of safety guards for other applications of high-speed cutting mechanisms, eg for hedge trimming and scrub clearing, particularly if flail rotors are employed which are rearward acting.

5 Standardisation

In line with the global needs of agriculture and the world manufacturing and marketing patterns for farm machinery, the trend in standardisation is towards an international approach. A draft international standard now being processed is concerned solely with the technical means of preventing accidents in relation to agricultural tractors, machinery and work places[4]. It has a section concerned with mowing machines, and the present proposals already recognise the need for special precautions to include guarding at the sides of rotary mowers. Before finalisation of this standard there will be opportunities for incorporating the latest findings and requirements.

Conclusions

To render multiple-disc and drum type rotary mowers safer to operators and bystanders, they need to be totally enclosed but in such a way that performance and accessibility are adequately maintained. Loosely hung, flexible curtaining can be effective in checking projected stones. At the rear and sides a minimum horizontal clearance of 300 mm between knives and flexible guard needs to be maintained.

Special precautions are essential at the front of all rotary and flail mowers. The minimum practicable depth of front check curtain depends to some extent on the physical characteristics of the material used; an important criterion is good sealing at the lower edge. On the basis of experience a high standard of protection is likely if the edge of the top cover from which any yielding front shield is suspended is located at least one and a half times as far horizontally ahead of the mower knives at the vertical ground clearance at the front, subject to a minimum horizontal distance of 300 mm. Because of the widely varying geometry of different combinations of tractor, cab and crop cutting equipment, studies to provide wider and more precise design guidance for front guard configuration are desirable.

Top covers need to be capable of preventing penetration by stones and metal fragments. Protective measures on the tractor to complement machine guarding include the use of unbreakable screens for the cab. Appreciable benefits in terms of operator safety could result from front mounting of mowers. Statutory requirements apart, it is in the serious interest of users to maintain the effectiveness of mower guards throughout the life of the machines; the designer can contribute by making provisions to facilitate this.

NB The information in this paper is provided without liability for any loss or damage suffered as a result of its application and use.

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The problems of ventilation and dust in farm buildings with particular regard to barn machinery

DUST in the atmosphere of buildings and the accumulation of dust on machinery, equipment and building surfaces gives rise to unpleasant working conditions and situations which may be hazardous to health.

The principle source of dust in buildings is grain which is either being moved or processed. Elevators, conveyors and machinery such as hammer mills all produce dust when operating. Pneumatic conveyors may also distribute dust over a wide area in a manner which is difficult to overcome without adversely affecting the efficiency of the unit. An important health hazard associated with mouldy grain is Farmer's Lung which may also arise from spores present in mouldy hay and other stored fodder including silage.

The atmosphere in livestock buildings contains dust from animals in the form of skin scales and fragments of feather and hair. This dust is usually mixed with fine dust from feedingstuffs.

Large dust accumulations may make floors and walkways slippery and increase the risk of accidents. Other problems which may arise include the risk of fire and pest infestation.

Normal ventilation rates used for buildings are of little value for the removal of dust since the air speed required to move dust particles is approximately 15 times the maximum airspeed used in ventilation to create satisfactory conditions for workers and livestock.

Improvements can, however, be effected by choice of appropriate machinery and the installation of suitable dust extraction systems, preferably at the time of installation. It should also be remembered that heavy accumulations of dust frequently indicate wasteful and inefficient methods of operation which cannot be justified in present circumstances.

Summary of a paper by W H Dempsey ARICS MRSH AIAgrE Agricultural Development Advisory Service, Newcastle-upon-Tyne, presented at the Autumn Conference of the Institution of Agricultural Engineers, in the Conference Hall, National Agricultural Centre, Stoneleigh, Warwickshire, on 14 October 1975.

The development of safety standards for small rotary grasscutters

by J M Anstey BSc MI Mech E MBIM

Historical background

THE English climate is, or perhaps one should say is normally, almost exactly what is required for the development of that fine close cropped lawn which is the centrepiece of the traditional English garden. Such lawns were originally maintained by scything, but the exercise of this delicate skill was gradually superseded during the 19th century by the development of the cylinder lawnmower. This type of machine, when properly set and maintained is ideally suited to the frequent cutting of fescue and other thin leaved grasses at heights of between ¼in and 1in.

In other countries, extremes of temperature and long periods of aridity require higher cutting, and the use of coarser grasses, conditions in which the cylinder lawnmower is much less efficient. This led to the development of the simple rotary mower, which quickly became the dominant type first in USA, and Australia, and then in continental Europe. The market for such machines grew rapidly with increasing prosperity, and in the USA at the present time it is estimated to amount to some 7 000 000 machines per annum. Under these circumstances, competitive pressures also increased, and the need for reduction in manufacturing costs was inevitably reflected in the designs produced.

The main components of a simple domestic rotary mower are, of course, the engine, deck, wheels and handles. For a given size of machine and type of crop, the principal factor affecting power demand and hence engine size and cost is the freedom with which the cut crop can be discharged from the deck or housing, and the larger the openings that can be provided the easier this becomes. The deck design is also influenced by the wheel size provided; smaller diameter wheels make the mower harder to push, and this has to be compensated for by reducing the drag between the deck and the crop by increasing the ground clearance relative to the blade height, particularly of the front and rear walls. The cost of handles is obviously affected by their length, and in addition, a reduction in handle length often makes possible a reduction in the size of carton and hence in handling and storage costs.

As a result of these competitive pressures, the design of rotary mowers tended to expose more and more of the blade to potential contact with the operator or bystanders, to offer less protection against the emergence of high speed foreign bodies such as stones, and to bring the operator's feet nearer to the danger zone. In consequence, a large number of accidents occurred, and a congressional commission on product safety in the late 1960's estimated that a total of 400 000 injuries had been inflicted by rotary mowers in one year in the USA.

The danger had, of course, been realised by the larger and more reputable manufacturers, and many moves were made toward self-certification schemes such as that operated by the Outdoor Power Equipment Institute (OPEI) and other bodies. These were, however, only moderately effective, and did not prevent a demand arising for stricter safety requirements with mandatory effect. Several countries, including USA, Germany, Australia and Scandinavia began to evolve standards with this purpose in mind.

In the UK, the rotary mower remained a small fraction of the domestic market only, catering mainly for the larger estate containing areas of semi-rough, and for local authority work. The emphasis here was much more on quality and performance, and we were fortunate in escaping most of the worst excesses perpetrated elsewhere. However, with increasing international activity in the standards making field, it was felt that the UK should play its full part, and to this end, work was initiated by BSI.

We now have in this country two published standards, namely BS 3456 Part 2 Section 2.32 1974 – *Requirements for mains operated electric lawnmowers*, and BS 5107 1974 – *Specification for powered lawnmowers.* The objective of the first of these is primarily to deal with the electrical hazards potentially present in the very large numbers of mains powered machines, both rotary and cylinder, currently being sold; it contains some provisions for protection against mechanical hazards, but it is intended in the longer term that these should be aligned with the provisions of BS 5107, work on which began later than on the electrical standard. Internationally, the International Commission on Rules for the Approval of Electrical Equipment (CEE) is in process of developing a counterpart to BS 3456 Section 2.32 while the International Standards Organisation (ISO) is dealing with the mechanical hazards presented by all types of powered domestic mowers. This paper is intended to discuss some of these mechanical aspects in respect of rotary mowers.

Standards development

The BSI committee responsible, AGE 20, sought first to identify the major areas of possible hazard. In so doing it had before it a draft prepared by its indefatigable secretary S G Tatem of BSI, drawn from the American, Scandinavian and Australian Standards already published, and the German DIN Standard in draft form was also considered; as well as our own Agricultural Field Machinery Regulations.

It was fairly easy, therefore, to spot the principal hazards, and it was possible to find an adequate and satisfactory way of dealing with most of these problems already set out in one or other of the pre-existing documents. Where possible one of these solutions was adopted; where a choice existed, it was made first on the apparent technical merits and if these seemed about equal, preference was given to the German approach in view of the UK's association with EEC, and the considerable market for British lawnmower exports in Germany.

However, in some areas, we were not satisfied with the solutions arrived at elsewhere and therefore had to develop a new approach, one of the more interesting examples being the test for foreign body ejection. Other countries specified so-called practical tests, all of them different, but which consisted in essence of surrounding the machine by some form of paper, card or board barrier, inserting various articles such as natural or artificial stones, ball-bearings, nails or wire, and then examining the barrier for perforations or damage. By the time AGE 20 came to deal with this problem, a good deal of International activity had begun both in CEE and ISO, and each country was advancing its own version of this test, assuring anyone who would listen that it had found its particular variety more repeatable, easier to perform and more realistic than any other. Faced with this situation, some of the manufacturers represented on AGE 20 began doing the tests themselves, and generously shared a good deal of the information thus derived with the Committee.

Immediately, the problems became apparent. The chief difficulties were that repeated testing of identical machines gave different results each time, and that such general conclusions as could be drawn from the test did not appear to be at all realistic in the light of practical experience. For example, using the German

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test method, which is probably more closely specified than most, a series of eight tests were carried out on a well-proven and well-guarded type, which produced five passes and three failures; the numbers of penetrations of the barrier in the operator zone varied from nil to five, where the maximum for acceptance was two. Careful observation of the tests indicated that the missiles (artificial stones of an abrasive ceramic material) were fragmented by the blade impact, and virtually all the fragments emerged through the discharge chute and were deflected by the guard onto the floor of the test cell, which was covered with a foam rubber and plastic artificial grass. The penetrations of the paper barrier were caused by ricochets from the floor. The amount of fragmentation and the resilience of the ground were unlike anything one would expect to find on lawns, and both produced large random variations from test to test. Furthermore, small missiles, which would cause no injury, still penetrated the barrier.

Poor repeatability and lack of realism are obviously totally unacceptable, as a basis for standardisation, and the Committee felt that modifying the test to overcome these disadvantages would take so long that it would hold up the issue of the Standard unduly. BS 5107 therefore now contains only a simple geometric requirement designed to ensure that nothing can emerge from a discharge aperture without first striking part of the machine. This provision is admittedly not an absolute assurance against the possibility of thrown object injury, but in all probability no such assurance is possible. It does at least exclude the most obviously hazardous designs, and in UK conditions at least is perhaps the best compromise between safety, functional efficiency and cost.

This approach was, of course, put forward by the UK internationally, but has not so far found acceptance; the main reason seems to be that in countries where the specification of requirements for lawnmower safety is the responsibility of Government agencies, political pressures make it difficult to accept a test which appears to the layman less stringent, and certainly less dramatic. Attempts are therefore still being made to modify the "practical" test to make it more satisfactory. It is generally agreed that the main problems are:—

(1) A selection of missiles which are representative of those actually found in actual use, but which are capable of being specified accurately.

(2) Simulating the effect of grass-covered soil by a reproducible substrate.

(3) Discounting the effect of emerging missiles which are incapable of causing injury, and weighting the remainder according to the likelihood of their producing injury, and to the severity of such a resulting injury.

A good deal of work has been done on various aspects of these problems, but so far almost the only positive result has been to illustrate how little is really known about any of them, and how widely the conditions of use vary from time to time and from country to country. This is particularly true of problems (1) and (2). In the USA, for example, quite a high proportion of the thrown object injuries are caused by pieces of wire whereas in most other countries stones are the chief culprits. Similarly, authorities in various countries quote the optimum cutting height for lawnmowing at anywhere between ¾" and 3", with correspondingly wide variations in rebound behaviour.

As a result of all this work, the test proposals grow ever more complicated, and the list of projects for research ever longer, while any solution appears as far away as ever, if not further. The latest development is due to the USA, who propose a test wherein the machine is suspended several feet above a sand bed, and the cardboard barrier comprises several layers of material to enable the penetrative power of the missiles to be measured. The barrier will be divided into zones both circumferentially and vertically, and different weightings will be applied to penetrations in each zone. In order to establish the weightings a large number of machines will be tested in this way, and then tested under various grass conditions while surrounded by a mobile barrier. It remains to be seen, however, whether there will be sufficient correlation between rig and field tests to enable conclusions to be drawn.

Conclusions

There appear to me to be some lessons to be drawn from the experience of several years work in the lawnmower standards field. Perhaps first and foremost, from the manufacturers point of view, is that unless the manufacturers themselves ensure that their products are safe and reliable, someone else will take over the job from them. Whoever does this is unlikely to be as well aware of the real nature of the problem as is the manufacturer, and he will consequently produce requirements that are more stringent and detailed than is really justified, and which may indeed make no contribution to safety at all. Once outside agencies do become involved, however, the manufacturer cannot stand aside; he must participate to the full and be seen to be striving from the common objective. After all, no business can thrive by killing its customers.

Secondly, those representing the consumer interests need to be aware of the danger of over-specification. It is obviously desirable that products should be as safe as reasonably possible, but there comes a point beyond which it is pointless to go. The search for perfect protection is often self-defeating; it is usually unobtainable and results merely in interminable delay, or in the adoption of safety devices which greatly reduce the convenience and functional efficiency of the product. More and more people then seek to frustrate them, often in ways which leave the danger worse than before. Cost, too, cannot be ignored; all the consumers have to pay for the devices specified for the protection of the tiny minority; rising cost can also oblige people either to retain old and dangerous equipment, or to revert to other methods which may have greater inherent perils. Were the unskilled users of rotary mowers to turn back to the scythe and bill-hook for example, leg and foot injuries would almost certainly increase.

It is all too easy to visualise a hazard which does not occur in practice; there should be solid evidence for the existence of a danger before precautions are imposed against it. Here, standards-makers are often not well served by government; such accident details as are available are often too vague to enable conclusions to be drawn. Clearly this is inevitable when attempts are made to report on all of a large number of incidents rather than a suitable sized sample; the right compromise must be made between the size of the net and the fineness of its mesh.

Uniform mandatory standards over large areas of the world have obvious advantages for international trade; the compensating disadvantages may not be so apparent. They include the fact that conditions vary widely from place to place, so that a major problem here may be negligible there, but if requirements so decree will have to be treated as if it were uniformly important everywhere. ISO has attempted to deal with this by seeking to define methods of test while leaving acceptance criteria for local determination, but this is often difficult to do in safety matters, where the question is often whether or not a specific product feature is permissible. Standards-makers seem to fight shy of incorporating recommendations, rather than requirements, in their specifications, but there is much to be said for this practice.

In a short paper such as this, one can only mention superficially a few of the topics which have arisen during an activity which has continued for several years, and indeed a detailed account would be tedious and unrewarding to anyone not directly engaged in this particular industry. The work itself, however, has been far from tedious, and has yielded many pleasures and satisfactions. One particular source of pleasure has been the opportunity to work in co-operation with many people, including one's competitors as well as governmental and consumer representatives, both in Britain and elsewhere. I would encourage any engineer or businessman to participate in standards activity whenever he may have something positive to contribute. Here I would like to acknowledge my debt both to my previous employers, Birmid-Qualcast Ltd, and to my present company, Wolseley Webb Ltd, for the opportunity to do this work, and to Wolseley Webb Ltd, for permission to present this paper, the opinions and views in which are, however, purely my own.

Simulation of Accumulation and Leaching in Soil

THIS is a further publication in the simulation monograph series. The book describes simulation models for the accumulation and leaching of chemicals in soils. It considers completely soluble substances (C1 ions), partly adsorbed substances (Na, K, Ca and radioactive Sr) and strongly adsorbed substances (Hg and radioactive Cs). The last chapter considers herbicides many of which are volatile and move in the gaseous phase. The model results are compared with laboratory and field data. Computer programmes for the models are written in CSMP–111. GS

Simulation of Accumulation and Leaching in Soil. M J Frissel and P Reiniger. Publishers: PUDOC, Wageningen, The Netherlands. Price: Dfl 20.00 £3.50.

See also page 111

The ventilation of farm buildings to mitigate the dust problem

by H W Prosser

1 Introduction

IN a paper such as this it is not possible to be specific or comprehensive and all that can be discussed are general principles and systems. In most cases where a problem is experienced the resultant action is a compromise between what is technically feasible and the cost.

Normally, dusts are classified as dusts when the particle size is above one micron, ie one millionth of a metre in diameter, when the particle size is under one micron the material is then usually called a smoke or fume. Throughout this paper, however, the term dust will be used to refer to any pollutant of suspended particles in air.

It has been stated that a health hazard to lungs exists when the particle size is between ½ micron and 6 microns but that pollens and other materials can give rise to allergic complaints in the range 20 to 60 microns. Some authorities state that pollen particle sizes vary from 4 to 80 microns. Incidentally it is said that the smallest particle that can be seen with the naked eye is 10 microns and fog particles vary from 5 to 50 microns. From this it is apparent that material of a particle size between ½ micron and say 100 microns should be considered. It is necessary to identify the particle size since capture and conveying velocities vary according to the size.

Unfortunately, it is much more difficult to deal with dust in an agricultural application than it is in an industrial installation. The aim should always be to capture the particles near or at the point of origin. In a factory the machines and processes which create dust are usually fixed installations which will not be moved at regular or frequent intervals eg a grinding machine or a paint spray booth. When the causation of the dust is in a fixed locality, it is possible to construct specially designed hoods and catchment devices that will trap the dust particles at source and not allow them to escape into the general atmosphere.

In agriculture the source can often vary as work progresses, for instance, augers and conveyors may be moved from point to point. This makes it very difficult to install fixed catchment hoods. In addition, the cost of reducing the dust in the atmosphere on a farm would be relatively much higher than in a factory when related to the number of workers who will benefit. This does not mean a farm worker should be expected to work in a bad atmosphere but may account for why so little attention and money has previously been paid to this aspect in agriculture.

Treatment of dust as a hazard may be considered in three parts — viz: (1) Catching, (2) Conveying and (3) Collecting.

2 Catching

Preventing a hazard is always better and cheaper than curing one after it has occurred and, in this respect, good housekeeping on the farm can make a significant contribution in reducing the dust problem. Many cases of dust in the atmosphere are caused by ill-fitting or damaged components which, if maintained or replaced would not allow dust to escape. An example of this is where connections between hammer mills and conveyor pipes do not match up exactly and a small blow results; not only does this create a dust hazard but also wastes food (and money) as well.

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Paper presented at the Autumn Conference of The Institution of Agricultural Engineers, held in The Conference Hall, National Agricultural Centre, Stoneleigh, Warwickshire, on 14 October 1975.

In cases where it is not possible to prevent the particles escaping, it is most desirable to catch them as near to the source as possible. If this is effected the volume of air required will be kept to a minimum and both initial cost and running costs will be as low as possible. If it is feasible a hood or cover should be constructed to enclose as much of the area around the source of dust as is possible. A hood with an extended skirt on three sides is often more efficient than a simple open hood.

Considering the airflow at the approach to a hood or dust inlet, the capture velocity can be related to the particle size, the lower the particle size the lower the capture velocity. Capture velocities can vary from almost nothing to over 1000 ft/min (5 m/s) but in the range under consideration up to 50 ft/min (0.25 m/s) would be needed.

Air moves towards a hood or duct to fill the depression caused by a fan and in an open atmosphere will approach the depression from all sides. In the case of a simple circular duct ending the region of influence will be almost spherical. Further consideration of this aspect is usually based on considering the constant velocity contours, these are the locii of the points of equal approach velocity. For the circular duct ending, with a velocity inside the duct of 1000 ft/min (5 m/s) the velocity contour for 100 ft/min (0.5 m/s) would be almost a sphere of radius about 0.9 times the diameter of the duct. Since the surface area of an expanding sphere varies as the square of its radius the approach velocity reduces quite rapidly the further one moves from the duct end. The velocity contour of 50 ft/min (0.25 m/s) is a sphere with a radius of about 1¼ times the diameter of the duct.

In the case where a duct is connected to a catchment hood the spherical effect will be distorted near the hood. Consider a long, narrow slot in the middle of a ceiling: the velocity contours in a plane at right angles to the slot would be semi-circular while the contours in the same plane of the slot would be a straight line with the ends rounded off.

It may now be obvious that if the source of dust is a point nothing more elaborate that a simple duct ending is necessary providing the point of origin is located as near to the centre of the duct as possible. If the source of dust is not one point (possibly rising from an open topped chain and flight conveyor) a slot or long narrow hood would be better. Naturally, a better solution with such conveyors would be to box them in so that no dust was released into the atmosphere, then one would only have point sources at the intake and discharge points but this may not be practical or economic.

If possible the direction of airflow should be from the occupied area, through the dusty area to the catchment hood or duct.

3 Conveying

Having captured and entrained the dust into a duct system it is now necessary to convey it to an area where it can be deposited safely. It is necessary to have at least 1000 ft/min (5 m/s) within the duct to get a capture velocity of 50 ft/min (0.25 m/s) just a short distance away. However, particle movement within the duct appears to be slightly different from when in the atmosphere and it becomes necessary to increase the duct velocity even more. Within the duct the particle bulk density is naturally increased and apparently there is an attraction to the side walls and to each other. If the particles start gathering into small groups their collective mass is increased and there seems to be more tendency to settle within the duct, particularly at junctions and corners. Therefore, it is preferable to have a duct velocity over 2000 ft/min (10 m/s) to keep the particles in suspension. Some authorities consider the velocity in the duct should be nearer 3000 ft/min (15 m/s) but this is more usual for conveying a material in bulk and our consideration now is relatively small quantities of dust.

Selection of the fan to be used is dependent upon where it will be positioned, the amount and type of dust involved and the system resistance. A system resistance is the pressure required to move a given volume of air through a specific installation. In the imperial system volume is quoted in ft^3/min and in the SI system it is quoted in m^3/s. Pressures are given as inches water gauge in imperial units and Pascals (P) or Newtons per square metre (N/m^2) in SI units (P and N/m^2 have the same numerical values). A brief consideration of the fans usually used may give some indication of their relative values. Axial flow fans have high efficiency impellers and non overloading characteristics so the motors are safe even if the estimate of system resistance is not correct. If the dust concentration is likely to be heavy, this type of fan must be mounted on the clean side of the collecting device as the impellers are usually aluminium alloys with little resistance to abrasion.

Centrifugal fans are more common for this application but there are many different designs available, each with its own characteristic. If the fan has to handle the dust laden air the radial (or paddle) blade centrifugal has the best resistance to abrasion and is self cleaning but has a potentially overloading characteristic and low efficiency.

A radial blade centrifugal fan requires maximum horsepower when operating at free intake and discharge (F I D) ie when running freely against no aerodynamic resistance. With this type of fan it is therefore safer to underestimate the system resistance but then, of course, the design volume (and velocities) may not be achieved in practise.

A backward curved centrifugal fan is more suitable from the point of view of power though it is generally speaking more expensive. The backward curved fan is inherently non-overloading as peak power occurs on the working part of the fan characteristic.

It is usually economic to connect up a series of hoods into a single fan. Under such circumstances a system resistance calculation must be carried out on the path which is likely to be the highest resistance. This is usually the path from the furthest hood to the fan. Having determined the highest system resistance, the fan is selected for a volume which is the summation of all the volumes required through the various hoods against the highest system resistance. Since the hoods nearest the fan will not require as much pressure as those further away, the system would be unbalanced without further action. In order to balance the system, slides or dampers are necessary in the low resistance paths. These are to increase the local resistance in order to balance the pressure requirements.

The calculation of system resistance is a subject in itself and is not therefore covered by this paper.

4 Collecting

In a few isolated cases it will be possible to discharge the dust laden air to atmosphere in an area away from all personnel but normally it will be necessary to separate out the dust. Heavier particles can be collected in a large settling chamber but these can only collect particles of greater than approximately 50 microns and the smaller, more dangerous particles will pass straight through. Settling chambers are usually fitted with internal baffles to absorb the kinetic energy from the moving particles. Settling chambers are not commonly used in agriculture due to the quantity of smaller particles that are likely to be in the dust but they could be very useful as part of a two stage collecting system. If followed by a fabric fitter or small high efficiency cyclone, a settling chamber can reduce the load on the second stage. The internal velocity of a settling chamber should be around 200 ft/min (1 m/s).

Cyclines are proprietary devices where the dust-laden air enters tangentially at the top and swirls around inside and the clean air is discharged from the centre at the top. Inside a cyclone there are two distinct vortices, an outer descending vortex and an inner ascending one. Due to centrifugal forces and a reduced air velocity the dust particles are deposited on the outer walls of the cyclone and in the inverted conical base. To select an appropriate cyclone a manufacturer would need to know the air volume to be handled and the type of dust being carried. It is not possible to calculate the aerodynamic resistance of a cyclone but manufacturers can quote the resistance for a given airflow based on previous experience and testing. Cyclones are suitable for collecting particles above 25 microns in size. They do not, therefore, collect the particles which cause lung damage but they may be sited in a position where the discharged air can do no harm.

The most common type of collecting equipment in agriculture is the cloth or fabric filter. This is usually a series of fabric tubes in parallel hanging down from a plenum chamber or pressure box though filtration is undoubtedly better if proprietary filter banks are housed in a large box something like a settling chamber. Cloth or fabric filters can be most useful since they can be effective down to about 0.3 microns depending on the type of fabric. Since these filters can be located in an area or separate room where no staff are present it is then not necessary to have such fine filtering and a material that collects above 5 microns is probably sufficient. It is not desirable to use a better filter than is necessary since the better the filtration the higher is the power required from the fan for a given filter area. There is such a range of fabrics that can be used that it is necessary to refer to the manufacturers to find out which would be suitable in a particular installation. The materials which are most commonly used for this application are reasonably efficient down to about 5 or 10 microns; at 5 microns they probably collect around 80% of the approaching particles.

With all collecting methods it is essential that they be inspected and emptied regularly. If they get overloaded with entrapped dust their efficiency deteriorates. In the case of fabric filters the efficiency of filtration will not be diminished but their resistance will increase and the volume of air throughput will be decreased. This will mean the catchment velocities then may not be sufficient to capture the particles at source and the overall performance of the system is diminished.

Finally, it must again be emphasised that good housekeeping is the most important feature of tackling a dust problem. Maintaining equipment, mills, conveyors etc. in good condition may even prevent a dust problem occurring. When it has occurred and a fan and system has been installed, inspection, maintenance and cleaning will keep the system operating effectively.

Ergonomics of tractor design with regard to work-place environment

by J Matthews BSc FIAgrE

1 Introduction

REVIEW papers on research into ergonomics aspects of tractor design have been published regularly[1,2] but progress in several areas covered by this general topic has been considerable. In the author's view this paper is well justified by the need to regularly update the latest information on research conclusions and developments of standards and regulations both for those working in the tractor construction industry and for others responsible for safety, the operation of tractors, or research into their design. This paper deals specifically with the design of operator's workplaces and cabs on tractors and does not cover some physiological and psychological aspects of the driver's work which are dealt with elsewhere. For the purpose of organising the information it is convenient to divide the topic into the basic workplace consisting of the seat and controls, the cab and the environmental factors. The length of the paper precludes dealing extensively with less conventional designs of tractors or with self-propelled machines. Neither is it possible to deal in any great depth with specialised tractors such as those for vineyards or tool bar implement mounting.

It must be emphasised that, in order to provide industry with a full account of the latest thoughts in the continuing international discussions of tractor standards and regulations some data is reproduced which has still not been agreed by formal international voting. This must therefore be regarded as unapproved and subject to change. Its exposure at this stage, however, should allow dissenting opinions to be expressed.

2 Workplace design

2.1 General

Design consideration should include siting of the workplace on the vehicle, visibility of the route and work being carried out by the tractor, provision of seating and hence the determination of the posture taken, plus the arrangement and design of controls including those characteristics of controls which will also affect posture in a dynamic sense. More detailed aspects of control identification and fundamental ergonomics principles which should influence their løng term design are dealt with in another paper[3]. It should be recognised that, although little fundamental research has been carried out, reversible seating and control stations have been applied, apparently successfully on more than one commercial agricultural tractor. The benefits of this feature must be largely judged subjectively and will often be specific to the individual tasks undertaken by the vehicle, largely in relation to the need for detailed viewing and accurate control. Workrate comparisons with the driver reversed have, however, been reported by Bull *et al*[4]. These show workrate advantages in forklift loading where a 25% increase in rate was obtained and some improvement in accurate rowcrop work. Clearly, although the principles of seating postures and controls described below have been drawn up with the conventional driver position in mind, they could also largely apply to the driver of a vehicle operating in a reverse direction when his workplace is turned through 180°.

2.2 Seating

The best dimensions and shape of tractor seat, including its length, width, hgight above floor position, its positional relationship to the steering wheels and pedals and its facility for adjustment to cater for variations in driver stature have been debated for many years[5,6]. One particular difficulty is the large range of human dimensions when covering different races and including women as well as men. Because of the space available on present tractors it is almost impracticable to cover the size range from 5th percentile women to 95th percentile men. It has been usual practice to rather forget women drivers! Another difficulty apparent in deliberations has been in allowing for both the more upright posture where the man sits sufficiently high above the foot platform that he can alternate standing with sitting and the more prone postures as in a motor car where the legs are largely horizontal and the body often sloped more rearward. The latter can be shown to provide for more effective operation of pedals[7] but does not allow standing and, if the backrest tilts too greatly backwards introduces difficulty in turning rearward. This problem is decreased with the use of flat platform cabs since in these the apparent desire, and often the ability, of the man to stand is greatly reduced.

Following the discussion in various bodies a draft International Standards Organisation (ISO) tractor seating standard has been produced[8]. Differences in the uprightness of seating are allowed for in that the total ability of the legs to reach both horizontally and vertically is defined (fig 1). In some other ways, for example the minimum horizontal and vertical adjustments of the seat, this draft standard represents somewhat less than the ideal but the author considers it to be a good practicable aim to follow at this stage, taking into account engineering constraints of space shortage above the tractor transmission and interference with possible seat movement by the hydraulic lift and other features of the tractor.

One feature of tractor driving is the need to monitor events all round the vehicle and particularly those in front and behind the tractor. Traditionally this results in much turning of the driver's trunk to view rearwards. It is often thought that this contributes to the spinal health hazards associated with tractor driving[9] in that the spine may often be subjected to vibration and jolting while twisted for rearward viewing. There would appear to be two ways of reducing the stress of turning of the trunk and possibly at the same time decreasing tiredness throughout the day. These are either to remove or reduce the need to turn rearward by using mirrors for viewing the implement working, or to swivel the seat. Experimental work with mirrors has been carried out by Sjøflot[10] and by Drayton[11]. Both investigations showed large reductions in the time spent turning to the rear (table 1) using a plane mirror of approximately 10^5 square mm area. Both were essentially short

Table 1 Comparison of the frequency of rearward turns and of the percentage of time spent looking behind with drivers of tractors with and without mirrors[11]

Frequency of turns (per minute)				
Subject	1	2	3	4
Without mirror	5.34	4.79	8.72	7.65
With mirror	0.37	1.39	0.28	1.66
Percentage of the looking rearward				
Without mirror	32.0	16.8	69.8	17.8
With mirror	0.4	2.3	0.6	3.1

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duration experiments, however, and it seems probable that there is still need for fairly extensive field trials on large numbers of tractor tasks to show the practicability of seeing all that is necessary and the advantage to tiredness over a long day of using mirrors.

The other way of reducing stress, providing a seat which swivels to reduce the angle through which the body must be turned, is being studied by Bottoms[12]. There are obvious constraints to the seat movement, namely the need to operate foot pedals and hand controls, particularly in an emergency, and therefore to have them readily accessible. Also the need to easily view forward to monitor the route taken. There could be a further security risk if the seat were freely swivelling so that the man's body was thrown sideways in sudden acceleration or decceleration of the tractor. For these reasons Bottoms has directed his studies on a seat with a 20° maximum swivel. It became equally apparent that the positioning of the effective pivoting point of the seat was critical, both in relation to providing the better foot positioning for pedal operation and to having a head position for easy viewing through the windscreen and rear windows. Bottoms proposes that the best pivot position is near to the forward edge of the seat pan (fig 2). In his experiments he measured the comparative activity of four relevant muscle groups, Sternomastoid, Trapezius, Latissimus Dorsi, and Lumbar Region both with the tractor horizontal and tilted as if working with the wheels on one side in the bottom of a furrow as when ploughing. His trials showed some decrease in the activity of the Trapezius muscle with the swivelling seat (table 2). Farm trials to confirm this apparent advantage with subjective data are in progress. If these are satisfactory and, bearing in mind that medical evidence of any benefit could only be assembled in health surveys over a long time, this relatively economically modest added feature, which has made its appearance recently on some overseas tractor models, should be encouraged.

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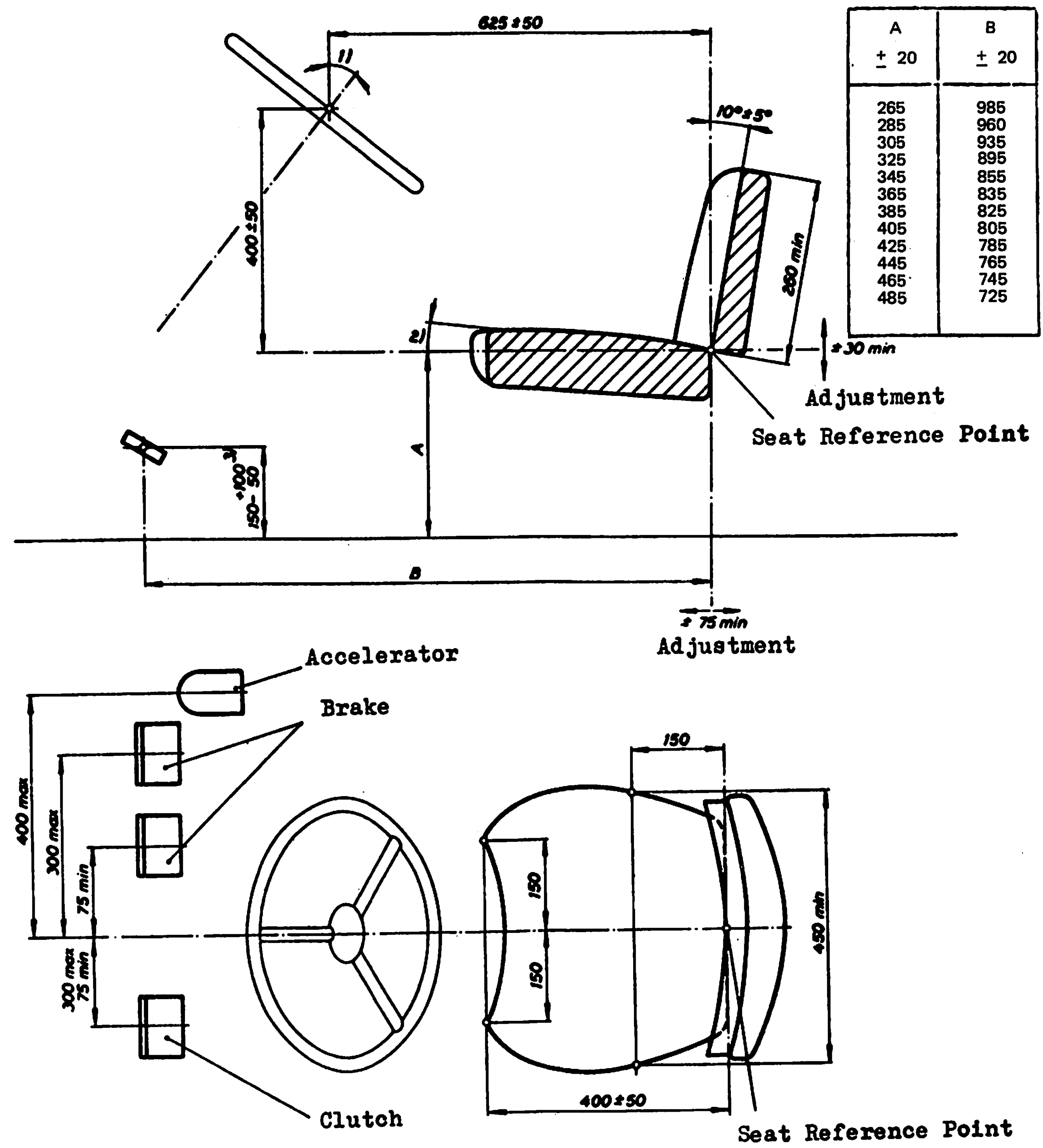
Fig 1 Specified tractor seating arrangement from ISO draft standard.



A ± 20	B ± 20
265	985
285	960
305	935
325	895
345	855
365	835
385	825
405	805
425	785
445	765
465	745
485	725

Table 2 **Results of swivel seat laboratory assessment showing mean integrated muscle activity and standard deviation for ten subjects**

Seat swivel, Degrees	Cab horizontal (H), of tilted (T)	Sternomastoid Mean	Sternomastoid SD	Trapezius Mean	Trapezius SD	Latissimus Dorsi Mean	Latissimus Dorsi SD	Lumbar region Mean	Lumbar region SD
0	H	1.21	0.44	2.09	1.06	0.77	0.27	0.54	0.12
	T	1.19	0.41	2.57	1.13	1.21	0.43	0.62	0.14
5	H	1.19	0.39	2.02	0.82	0.86	0.40	0.54	0.14
	T	1.20	0.39	2.72	1.36	1.28	0.42	0.65	0.19
10	H	1.17	0.44	1.95	0.87	0.75	0.21	0.58	0.20
	T	1.14	0.37	2.49	1.17	1.20	0.35	0.65	0.17
15	H	1.14	0.42	1.93	0.84	0.81	0.25	0.53	0.14
	T	1.11	0.34	2.39	1.01	1.20	0.40	0.64	0.16
20	H	1.15	0.37	1.90	0.76	0.84	0.27	0.58	0.20
	T	1.08	0.35	2.41	1.56	1.27	0.43	0.68	0.16

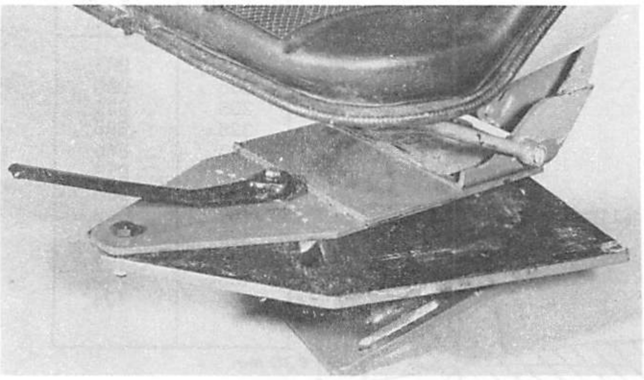


Fig 2 NIAE arrangement for allowing the tractor seat to swivel.

2.3 Controls

A British Standard dealing with the comparative location of principle controls of the tractor has been in operation for some time[13]. Over the last two to three years this has also been the subject of an international standard draft which has generally required the same arrangement as the British Standard. One particular difficulty was the direction of operation of the hand governor control lever. It has been traditional, perhaps from the earliest times when a simple rod control with finger ring was pulled out to increase engine speed, to associate rearward motions with speed increase, even when using the throttle lever pivoting essentially at the centre of the steering column. However, it would be claimed by ergonomists that this was the opposite of the stereotype of control direction and effect and that this conflict with the stereotype would be particularly dangerous during a time of critical emergency, for example when the tractor had become out of control or was about to overturn, when the driver would probably revert to the stereotype form. The author has heard accounts of three such incidents where the control was operated in the wrong direction. However, if a change were made to the traditional arrangement errors may be made as a result of previous training. The solution adopted in the international standard draft is to use the stereotype arrangement of moving the control forward to increase speed in association with a governor control lever on the instrument panel. With bigger tractors there has already been a change to this type of control and it is hoped that it will also happen with the smaller tractors when more sophisticated cabs are fitted so that in the longer term it will be possible to revert generally to stereotype.

A separate international standard draft covers the maximum force to be required to operate principal hand and foot controls (table 3). Again the problem of range of human ability taking into account race and sex, was apparent at the drafting committee meetings. The data on which the original proposals

Table 3 **Maximum operating forces for tractor controls proposed within the International Standards Organisation**

Device to be operated	*Control member type*	*Actuating force to operate control member N*	*Note*
Service brake	Pedal	600	Pressure
	Handlever	400	Traction
Parking brake	Pedal	600	Pressure
	Handlever	400	Traction
Clutch	Pedal	350	Pressure
Dual clutch		400	
PTO coupling	Pedal	300	Pressure
	Handlever	200	Traction
Manual steering system	Steering wheel	250	Applies when changing from forward drive into the angle of turn needed to achieve a turning circle of 12 m radius
Power assisted steering system with failure of the power assisted steering force		600	
Hydraulic power lift system	Handlever	50	Pressure and traction

were based were from relatively recent work in Sweden[14] although there are also much earlier data[15]. Some research demonstrates that strictly the maximum force should be related to the position of the control but for simplicity in the standard single maximum force figures only are given for each type of control. Neither do these figures cover fully the range of strengths of men and women. However, two contentions are probably justified in answering these criticisms. Firstly, the maximum values occur on many controls only occasionally, when exagerated corrections are being made. Secondly, women working in agriculture are likely to have above average strength due to the physical content of much of the work.

Although fundamentally different controls have been suggested, for example 'joy-sticks' to replace steering and speed controls there is little sign of their early adoption. This is made less likely due to the similarity between the principle controls of tractors and those of road vehicles where with most tractor drivers also driving a car it would probably be a retrograde step to design the controls differently.

3 Cabs

3.1 Overturn protection

Pendulum impact strength tests have been in use for more than ten years in the UK[16] and for more than 15 in Scandinavia during which time the NIAE for example has carried out over 600 such tests. During this time the most significant change to the test procedure has been the increase in the severity of the blow to the rear of the cab particularly on larger tractors, due to the continuing research into overturning severity showing that with larger vehicles in a rearward overturning accident, relatively high energies can be absorbed[17]. More recently further refinements have been proposed to the OECD and ISO codes to take into account the characteristics of less conventional tractors, for example tool carriers or long wheel base vehicles. These refinements if accepted will have the following effects:

1 To allow the use of the measured moment of inertia of the tractor about its rear axle to define the rear blow energy as an alternative to an approximation using the weight and wheel base (fig 3).

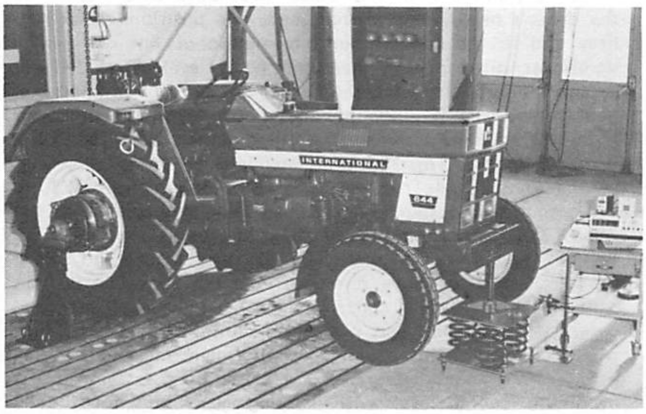


Fig 3 Arrangement of pivots and springs for tractor pitch, moment of inertia determination.

2 The elimination of the rear blow to four wheel drive tractors where they have 50% or more of their weight on the front axle, since there is no evidence that these overturn rearwards.

3 A restriction on the tractor weight range of the test to 6000 kg maximum to avoid excessive impact velocities of the pendulum, which might be much higher than the effective velocity for an overturn.

A more significant move likely within the next five years, however, is to carry out strength tests by static application of forces. Such methods, already employed extensively for safety cabs for constructional vehicles, have the following advantages over the pendulum tests:

1 More precise application of energy to the cab since the somewhat variable sharing of energy between distorting the cab and moving the whole tractor against its constraints is eliminated.

2 Allowing design or constructional weaknesses to be examined beyond the acceptable energy limits since the static force may be applied beyond the minimum required to pass the test. In particular it can be assured that the structural stiffness does not decrease significantly near the test limits and therefore lead to a risk of failure in a multiple roll situation.

3 Performance under a static test may be more easily predicted at the design stage saving time in poor designs needing retesting.

There are, however, two main difficulties preventing immediate acceptance of the existing codes for static tests and on which research considerations and discussions must now be concentrated:

1 Determination of the correspondence between energy levels absorbed by the cab in pendulum tests and those specified in static tests, bearing in mind the sharing in the pendulum test between cab distortion and tractor movement.

2 Yield strength enhancement in steel resulting in higher forces being generated at the mounting points under the dynamic conditions that is possible with static force application.

It is likely that both these snags will be overcome and static testing will be accepted ultimately.

3.2 Ergonomics design

Once the strength of the cab design has been assured and techniques established to measure this, the regulating bodies have turned their attention to ensuring that the other functional, and particularly the ergonomics, aspects of design are satisfactory. Several national requirements have been established for such aspects as the internal dimensions, the numbers and siting of escape means, and the design of steps. Largely to ensure harmonisation of these requirements internationally an international standard draft has been produced (table 4), defining the minimum internal dimensions, the minimum number and size and access of exit points and the dimensional requirements of steps. It should be pointed out that these requirements in the standard are practicable only for conventional tractors and that on narrow or vineyard models, for example, it is not possible often to provide such desirable features for the driver.

Table 4 Minimum dimensions for tractor cabs proposed within the International Standards Organisation

Dimension	*Minimum value mm*	*Preferred value mm*
Main door		
Overall height	1350	–
Width at 1350 mm	250	450
Width at 1100 mm (shoulders)	450	650
Width at 750 mm (hips)	470	650
Width at door sill	150	250
Emergency exits		
Square	510 x 510	600 x 600
Circular	610 dia	700 dia
Rectangular	400 x 610	470 x 650
Internal dimensions		
Seat ref point (SRP) to ceiling	1000	–
SRP to rear (at 900 mm above SRP)	150	–
Elbow clearance (from centre to sides)	450	–
Steering wheel to cab surfaces	75	–
Hand control to cab surfaces	50	–

Access is one factor which has been much discussed in the past, particularly on the first generation of cabs which were mostly fitted retrospectively to tractors not originally designed to take them. Undoubtedly ease of access can be important and probably have a significant effect on the tiredness and temper of the driver by the end of a day when he is required frequently to climb on and off the tractor, for example to open gates,

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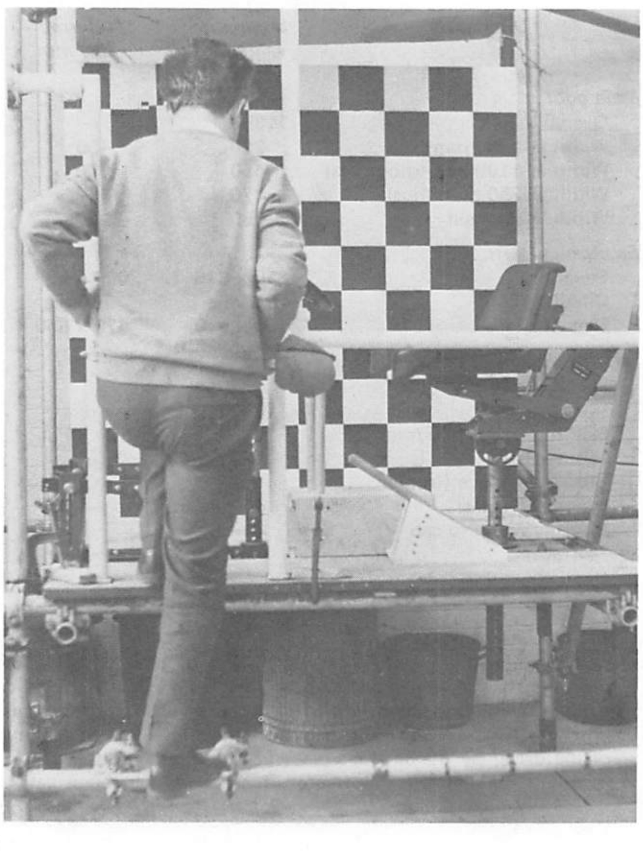
Table 5 **Summarised results of heartrate and subjective rating of various doorway arrangements in preliminary studies at NIAE of access arrangements to tractor cabs**

	Door position		*Door width mm*						*Platform width mm*					
			380		460		460/230		445		520		595	
	Front	rear	F	R	F	R	F	R	F	R	F	R	F	R
Pooled heart beat score (Low score best)	325.4	274.6	110.3	92.0	99.8	89.6	115.3	93.0	110.4	92.4	107.5	84.0	107.4	98.2
Order within class	2	1	5	2	4	1	6	3	6	2	4=	1	4=	3
Order overall			10=	3	7	2	12	5	10=	4	8=	1	8=	6
Pooled subjective rating score (High score best)	242.5	357.5	69.2	114.2	118.0	143.3	55.3	100.0	51.0	116.6	79.4	123.6	112.1	117.3
Order within class	2	1	5	3	2	1	6	4	6	3	5	1	4	2
Order overall			10	6	3	1	11	8	12	4=	9	2	7	4=

unblock an implement in difficult conditions or manually load a trailer. One farmer has reported recently observing his man leaving the tractor 40 times in one hour. For these reasons we are studying doorway, step and seat layout with regard to the physical effort of entering and leaving (fig 4). Early experiments reported by Bottoms[2] indicated that heart rate as a measure of physical effort and subjective judgement of convenience of access correlated well with one another and both displayed significant differences between different arrangements (table 5). The main experiment now in progress will initially cover a range of doorway sizes and shapes, different doorway positions as far as this is allowed by the position of the wheel, and varying space within the cab between seat, stearing wheel and mud-guards. One of the problems in such laboratory work is the extent to which one can introduce hazards such as mud on the floor or steps with a consequent significant risk to the experimental subjects. Clearly one cannot deliberately introduce real injury risks so that careful additional examination of the

Fig 4 Rig for investigating the relationship between tractor cab door size and shape and ease of access.



possible influences of these factors is necessary to ensure a similar relativity of the different designs under difficult field conditions of mud, low temperature and wet surfaces and in the more equitable conditions of the laboratory.

Bulky clothing is of course a factor which needs to be taken into account in laboratory work.

4 Environment

4.1 Noise

To date tractor driver noise measurement in the UK has been either to the procedure in the British Standard Safety Cab Test[16], or to the OECD Safety Cab Test Code procedure[18]. These two techniques differ only in detail, largely for reasons of non-synchronisation of their evolution. In practice the only real difference is the location of the microphone which in the British Standard Code is defined with respect to the seat reference point and in the OECD procedure with respect to the driver's head. We find that these two positions differ very little and to the best of our information do not represent a significant difference in measured noise level. The UK will certainly attempt to have the OECD test brought in line when opportune on the grounds that the relatively recently produced ISO draft standard also specifies microphone position as in the British Standard. This ISO draft standard which was drawn up by the Agricultural Tractor and Machine Committee TC23 has also been fully discussed with a representative group of TC43, the Acoustics Committee and is now being voted upon internationally. As with the current versions of the British Standard and OECD Codes referred to above it records the noise level in dBA in contrast to the earlier codes using sones. The draft standard covers self propelled and pedestrian controlled machines but, whereas noise on this equipment is normally measured during work, the tractor measurement consists of a search for the maximum sound level with varying gears and loads. The relativity between the maximum noise measured in the test and the equivalent continuous level during normal farm work was the aim of a tractor driver noise exposure survey carried out by Stayner[19]. He found some evidence that tractors were worked at a lower noise level and hence lower power output when the maximum noise was high, compared with vehicles which had a lower maximum noise (table 6). This seems to support the hypothesis often put forward that noisy tractors will not be used to full potential and hence its corollary that noise reduction at least in part pays for itself by increased work. The survey also shows that at this stage, where the large majority of tractors are fitted with noisy cabs, even though the drivers do not normally work at maximum noise for more than a small proportion of tasks, the equivalent continuous noise level is in a large proportion of the cases greater than 90 dB(A), the generally accepted limit in other industries (fig 5).

Recent research at NIAE into improved or more economic methods of reducing noise in tractor cabs has included three specific areas of study. With application of quieter cabs where there is a risk of single standing wave components of noise causing annoyance, a method of two dimensional modelling of

Table 6 **Comparison of field noise levels and test levels (maximum noise) for the same tractor models**

Test level dB(A)	*Av'ge field level for models with given test level dB(A)*	*Difference dB(A)*
85	87	+2
95	88	−7
98	91	−7
99	92	−7
100	92	−8
101	94	−7
102	91	−11
103	92	−11
106	93	−13
109	94	−15

the shape of the internal space of the cab has been developed and validated (fig 6)[20]. This allows the shape of the cab to be set up and varied in the quarter scale model and by using sound of wave length scaled by the same amount provides corresponding standing wave patterns to those in the cab. These may be examined and, usually by relatively small dimensional changes, the patterns can be changed so that a node and hence minimum noise intensity of the particular wave will appear at the driver's ear rather than an anti-node or corresponding maximum intensity.

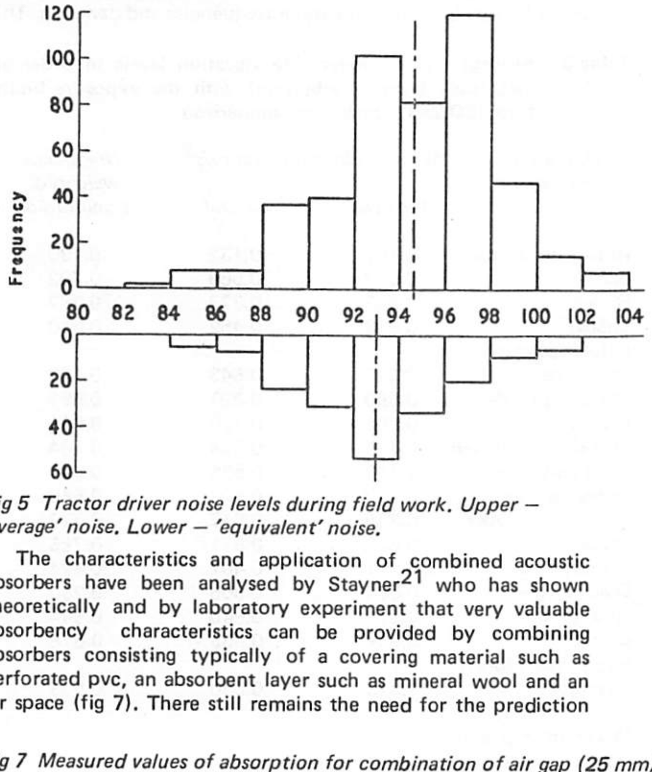


Fig 5 Tractor driver noise levels during field work. Upper — 'average' noise. Lower — 'equivalent' noise.

The characteristics and application of combined acoustic absorbers have been analysed by Stayner[21] who has shown theoretically and by laboratory experiment that very valuable absorbency characteristics can be provided by combining absorbers consisting typically of a covering material such as perforated pvc, an absorbent layer such as mineral wool and an air space (fig 7). There still remains the need for the prediction

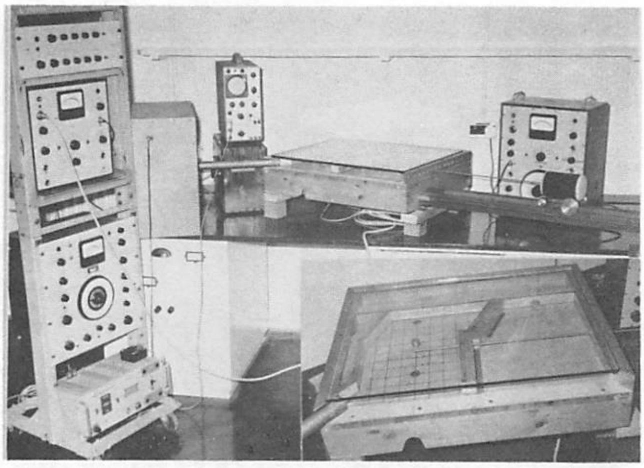


Fig 6 Laboratory equipment including a small scale two-dimensional model of a tractor cab to study sound standing waves.

of performance to be checked in a real cab fitted to a tractor. Finally Talamo[22] has reported experiments to show to what degree noise level in a cab arising from the transmission of noise from external sources through panels can be predicted from a knowledge of panel characteristics. He has shown promising agreement between the internal noise level and the individual components calculated from a knowledge of the level at a number of points outside the cab and the transmission losses of the corresponding panels.

One aspect of the employment of cabs both noisy or quiet, particularly since the latter for noise and climatic reasons are becoming more completely enclosed, is isolation of the tractor driver from external sounds which he should hear. These may be for example warning cries or machine noise which informs the man of the correct or malfunctioning of the implement's components. The same problem arises from the use of hearing defenders. Talamo has reported two series of experiments at NIAE to examine this acoustic isolation[23,24]. In the first the effects of the screening caused by noisy or quiet cabs or by the hearing defenders, plus the masking effect of engine noise or cab generated noise has been investigated. This work suggested that the discrimination of external sounds shall be better with either the quiet cab or the hearing defenders than with the noisy cab due to the avoidance of temporary hearing threshold shift with either of these, maintaining the ear's ability to discriminate. In the second experiment[24] recorded cries were replayed to drivers in the same variations of noisy and quiet cabs and with the noisy cab plus hearing defenders. The sound sources were arranged at various points around the tractor and sound intensities were adjusted to correspond to distances between the tractor driver and the person shouting varying between 3 and 12 m. The driver was given a simulated task to provide a similar degree of attention to real tractor driving work (fig 8). These experiments showed the serious interference

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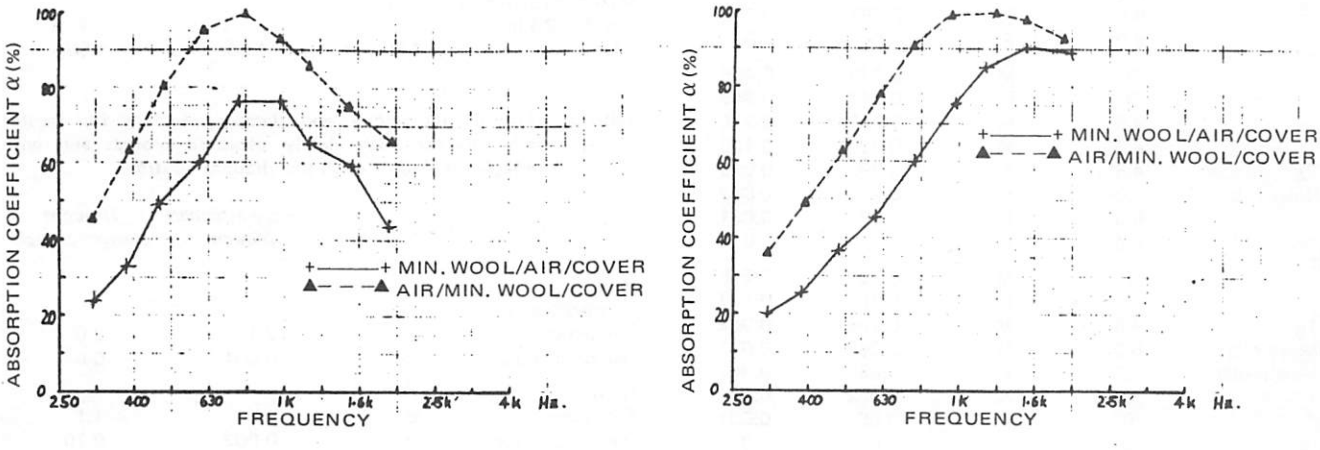
Fig 7 Measured values of absorption for combination of air gap (25 mm), absorbent backing (25 mm mineral wood, 112 kg/m^3) and perforated cover for two different cover materials.



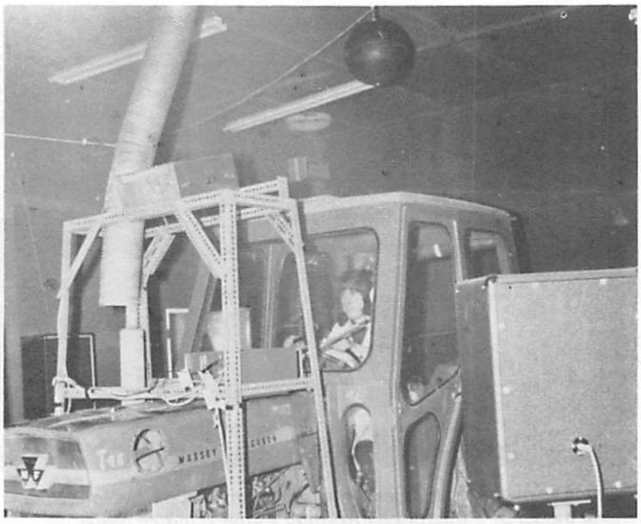


Fig 8 Tractor with simulated driving task in noise chamber to study the perception of sounds external to the tractor.

of all cabs with hearing and with identification of the source position. Essentially there is little hope of the effective identification of a cry at more than 3 m from the ear of the driver (table 7).

Table 7 Probability of hearing cry and of correctly locating direction with various acoustic circumstances

Tractor/ cab condition	*Simulated distance m*	*Type of cry sex*	*Probability of hearing cry*	*Probability of estimating direction in an arc of ± 45°*
	3	M	1.0	0.968
	3	F	1.0	0.906
T_1	4.5	M	1.0	0.875
Control	6.0	M	1.0	0.843
no cab	4.5	F	1.0	0.875
	9	M	1.0	0.937
	6	F	1.0	0.718
	9	F	1.0	0.718
	3	M	1.0	0.875
	3	F	1.0	0.75
T_2	4.5	M	1.0	0.750
No cab	6.0	M	0.968	0.718
+ engine	4.5	F	0.937	0.531
	9	M	0.843	0.656
	6	F	0.781	0.531
	9	F	0.218	0.156
	3	M	1.0	0.656
	3	F	0.875	0.406
	4.5	M	0.875	0.562
T_3	6.0	M	0.562	0.343
Quiet cab	4.5	F	0.375	0.218
	9.0	M	0.250	0.187
	6.0	F	0.281	0.218
	9.0	F	0	0
	3	M	0.875	0.406
	3	F	0.343	0.343
	4.5	M	0.312	0.218
	6.0	M	0.218	0.125
T_4	4.5	F	0.093	0.093
Noisy cab	9.0	M	0.125	0.062
	6.0	F	0.031	0.031
	9.0	F	0	0
	3	M	0.781	0.218
	3	F	0.281	0.187
T_5	4.5	M	0.156	0.062
Noisy cab	6.0	M	0.062	0.031
+ ear muffs	4.5	F	0.093	0.062
	9	M	0.062	0.031
	6	F	0.062	0.031
	9	F	0	0

The outstanding problem is of limiting the noise to an acceptable level on tractors without cabs. This is needed in situations where a full cab would interfere with the work, for example in hop gardens or orchards and is also likely to be demanded by some overseas countries particularly in Mediterranean areas where the climatic protection of the cab is not required. We have just started work to see how much reduction in noise level is possible when using engine covering techniques, bulk heads between the engine and driver's workplace, workplace floors and when giving maximum attention to minimising individual component noise emmission, for example that from fans, exhaust silencers and inlet silencers.

4.2 Vibration

The International Standard dealing with human tolerance to shock and vibration (IS 2631) was published in 1974[25], with further work still in progress to extend it to deal with frequencies below 1 Hz and to improve some other aspects of its ability to deal with complex vibrations[26]. The lower frequency range could be important particularly in relation to suspended cabs built for tractors. The survey of vibration levels in practical agriculture by Stayner and Bean[27] has confirmed high levels with respect to the International Standard (table 8) and shown the relationship between these ride levels and the size and weight of the vehicle. Work by Crolla[28] on hydraulic draft controls has demonstrated the very important influence of plough damping through the three point linkage on tractor ride. Vibration reductions of up to 40% were shown and table 9 shows the influence of implement coupling on natural frequencies and damping. This

Table 8 Average tractor driver ride vibration levels in order of magnitude (vertical vibration) with the exposure limits from ISO 2631 shown for comparison

Operation/ Implement	*Average vibration level m/s²*		*(frequency weighted)*
	Vertical	*Lateral*	*Longitudinal*
Rotary cultivator	0.152	0.132	0.190
Baler	0.513	0.569	0.702
Roller	0.533	0.372	0.387
Loader	0.613	0.459	0.510
Potato spinner/ harvester	0.617	0.643	0.183
Manure spreader	0.690	0.507	0.695
Disc harrow	0.706	0.730	0.631
Mouldboard plough	0.716	0.524	0.504
Light cultivator	0.749	0.536	0.571
Heavy cultivator	0.772	0.503	0.540
Fertiliser spreader	0.835	0.617	0.727
Trailer	0.838	0.571	0.785
Mower	0.851	0.407	0.424
Drag harrow	0.865	0.365	0.250
Sprayer	0.871	0.546	0.544
Drill	0.959	0.533	0.678
Hay turner/tedder/ swather	1.319	0.630	0.533
Maximum exposure level – 8 hours/ day	0.70	0.45	0.45
Maximum exposure level – 2½ hours/ day	1.60	1.00	1.00

Table 9 Natural frequencies and damping factors for tractor only, tractor with rigidly attached plough and with plough coupled through the draught control

Co-ordinate	*Tractor only*	*Rigidly attached plough*	*Draught control plough*
Vertical vibration			
Frequency	2.2	2.1	2.0
Damping factor	0.001	0.001	0.03
Pitch			
Frequency	2.8	1.4	1.1
Damping factor	0.001	0.002	0.70

perhaps then is a significant factor in deciding whether one should use mounted, semi-mounted or trailed ploughs. We have little information on the influence of other soil engaging implements but this is clearly an area for further study.

To help standardise ride measurement an international standard draft has been drawn up bearing a close relationship to IS 2631 and covering tractors and self-propelled machine vibration in the three principle axes. A more specific and detailed international standard draft has been produced to cover vibration and other tests for tractor suspension seats. This document is very similar to the draft EEC Code; the vibration test which may be carried out with a seat on a tractor operating over an undulating test track or on a vibration rig, being an evolution of BS4220[29].

Additional information on the performance of seat suspensions has been reported by Stayner and Bean who have studied changes in seats' abilities to absorb vibration throughout life on the farm[30]. They have shown that significant changes in isolation are common (table 10) but that these changes do not follow any consistent trends. It seems likely that the changes are mainly related to variations in the friction of bearings and perhaps the most valuable conclusion to be drawn from this work is that much greater attention should be given to the design of suspension bearings if seats are to consistently give a useful improvement in ride vibration throughout their life.

Table 10 Variation in suspension seat transmission factor with period of farm use, mean values for four different seat models (5 of each model) %

Seat model	*New*	*6 months*	*12 months*	*24 months*
A	100	83	90	83
B	105	104	109	118
C	–	78	104	83
D	–	98	111	87

As has often been pointed out, a suspension seat only improves the vertical component of the ride whereas, as shown by the survey of Stayner and Bean[27], the horizontal component is on many jobs also unsatisfactory and it is desirable that in the long term more fundamental development be undertaken to reduce the other components of vibration. There appear to be three ways in which this can be approached:

(a) To rearrange the masses of the tractor and the driver location so that moments of inertia are as high as possible and the driver sited as near as possible to the centres of rotation.
(b) To incorporate a cab with its own suspension having attenuating characteristics to at least pitching and rolling vibrations as well as vertical.
(c) To fit a suspension to the wheels or axles of the tractor again designing it to be capable of reducing all the important components of vibration.

Good progress is being made with the development of suspended cabs. Work done by Hilton and Moran at NIAE[31] has led to a cab with suspension being built, the suspension having means of attenuating vertical, pitch and rolling motions. Vibration reductions with respect to the levels on the tractor chassis of 75% vertical, 70% pitch and 60% roll vibration are possible with similar results being obtained over the artificial undulating test track and also in practical work such as harrowing or mowing. At the time of writing structural strength tests have been carried out on the cab and preparations are being made for a two year period of farm work (fig 9). This extended period of practical work is necessary to establish the following facets of the cab's use:

(a) The extent to which a tractor fitted with a suspended cab is worked at higher speeds or whether, alternatively, the driver opts for the greater level of comfort afforded at conventional speeds.
(b) The effect of the presence of the cabin on workrate and hence its productivity value to the farmer.
(c) The extent to which psychological feelings of instability within the cab limit the vibration isolation which can be arranged.

Fig 9 Tractor fitted with NIAE experimental suspended cab.

(d) The extent to which the cab, either because of its freedom from vibration or because of its relative motions compared with the tractor, interferes with the visibility of work or the monitoring of tractor or implement functioning or of work quality.

Suspended cabs seem likely to be produced in commercial form within a period of perhaps five to ten years. In addition to the NIAE research we have had the opportunity to learn of developments in Holland and by some tractor manufacturers. There has been less work on the other options above, the rearrangement of tractor masses or the use of wheel suspensions. However, NIAE are developing a computer method of simulation of the dynamics of the tractor with the aim of identifying the amount of ride improvement by these other methods in comparison with that using the suspended cab. It is already clear from measurements made over the undulating test track that significant ride vibration level differences are possible with relatively small changes in tractor design or fitted equipment (table 11)[9].

Table 11 Examples of the influence of tractor design on driver ride vibration severity (rms vibration weighted according to ISO 2631)

Tractor weight kg	*Other features*	*Simulated roadway surface at 15 km/h, m/sec^{-2}*	*Simulated rougher surface at 5 km/h, m sec^{-2}*
1600	Track width 1.4 m	2.7	1.45
	Track width 1.8 m	2.6	1.35
2100	–	2.3	1.4
2700	–	1.6	1.3
1750	Cab fitted	2.3	1.6
	No cab	2.8	2.2
2050	Tyres severely worn	3.1	1.7
	Good tyres	2.5	1.4

4.3 Climate

There has been a very large increase in the attention given to the control of climate inside tractor cabs over the last five years. In the early cabs there was little need for heating since heat losses from the transmission were directly fed into the driver's cab space whilst the avoidance of high temperatures in the summer was normally accomplished by removing doors and fully opening windows and in some cases removal of the cladding. The adoption of more complete cabs, however, with their own floors, both for acoustic control and to improve the access and driver manoeuvrability within the cab has cut the cab space off from the heat source so that some heating is probably necessary in these cabs. In the summer ventilation would seem to be the minimum requirement.

Much is known about optimum climatic conditions for

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human comfort[15] but there are several specific factors in tractors with cabs which require individual consideration and to some extent limit the very general approach used for offices and buildings:

(a) The cab has a great deal of glass surface and therefore the driver is subject to high radiant heat loading.
(b) There are significant reflections from sources on the tractor both inside and outside the cab.
(c) Within such a relatively small space with heat sources at the engine and transmission together with the sun, temperature gradients are almost inevitable.
(d) The operator is often functioning at a significant work-load possibly varying from 1-5 Kcal/min.
(e) The man frequently needs to climb out of the cab to give attention to the implement and therefore must be dressed for external climates.

The International Standards Organisation has discussed standards for:

(i) Pressurisation of the cab to exclude dust — this standard has been voted upon internationally and will probably shortly be published.
(ii) Tests for demist and defrost systems — this standard has been passed for international voting.
(iii) Air conditioning systems — so far there has been a lack of agreement on this document and further discussion has been postponed for three years to allow more data to be gathered.

It is probably worth dwelling briefly on the disagreements in relation to tests for air conditioning systems since they demonstrate the areas of outstanding problems. Firstly, such tests must be carried out in a hot environment which represents the worst conditions in which the equipment will be expected to operate. Tractors to be used in south and central America and other tropical areas are likely to suffer much more rigorous conditions than those used exclusively in Europe, for example. It may well be that different environmental standards will need to be considered for the tests and over the next two years or so it is clearly important that the industry decides under what climatic conditions tractors are likely to work with either air conditioning or forced ventilation systems.

Secondly, these conditions can be encountered in the field or reproduced within an environmental chamber. To allow round the year development testing it is clearly advantageous to be able to carry out the work inside a chamber. It is, however, difficult to simulate in such a chamber the effect of radiant heat from the sun and also to simulate the problem of reflected heat. The committee did not therefore think that the state of the technology allowed either an external environment or a chamber to be specified as equivalent options.

Thirdly, the draft proposes the ASHRAE comfort guide as an objective condition. There is, however, considerable doubt still about the allowable tolerance around the objective temperature and its relationship with the level of physical work. Finally, there are no valid data about allowable temperature gradients or air flows although these data are now being established.

Undoubtedly tests and performance specifications for air conditioning and ventilating systems will be established, but meanwhile some of the outstanding problems are being solved within a programme of research into cab climates by the Swedish Institute of Agricultural Engineering[33]. This work which still has to be finally reported upon has already shown the influence on driver comfort of the temperature external to the cab (fig 10). It has also shown that although different people are sensitive in different parts of the body to temperature, one can make sensible proposals about allowable temperature gradients. For example it has been shown that a gradient which results in the feet being 6°C warmer than the head is acceptable, whereas an 8°C difference becomes unfavourable. When the feet are cooler than the head the minimum differential for discomfort is within the range 4-6°C. Summer conditions are well known to cause over-heating and Eriksson has shown data which indicates the important effect of the forced ventilation[34]. Without ventilation in a 26°C ambient, environmental temperatures within the cab could exceed 40°C. With forced ventilation of 15 m^3 of air per minute cab temperatures may be restrained to 30°C. He considers, however, that there is some need to investigate the maximum speed and siting of

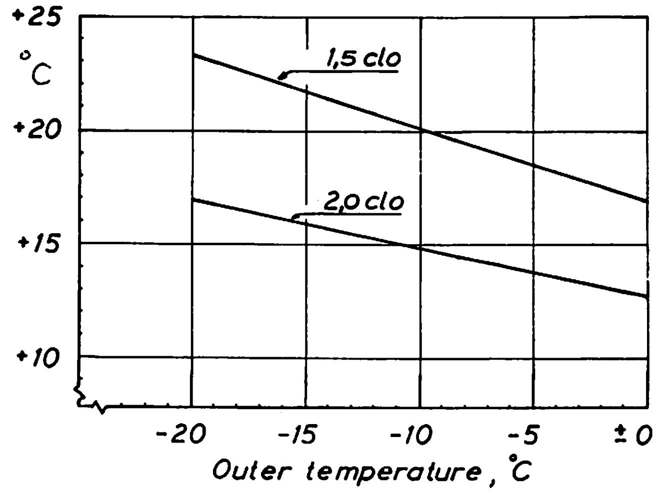

Fig 10 Subjectively optimum temperature within the cab for a given activity and two types of clothing in relation to external temperatures.

high velocity air streams needed to ventilate the cab. Clearly attention could also be given to the use of tinted glass. This is clearly an area where much further valuable information should arise within the next year or two. Meanwhile it would be wise for the industry to gather further information on conditions under which their cabs may be used. On the whole, the author is inclined to feel that air cooling will not be needed in this country but, as with our motor cars, forced ventilation will be very important.

5 Future development

It would appear that one of the earliest needs in further tractor ergonomics is to carry out detailed task analyses to discover the needs of the driver in visibility, operation of controls, decision making, etc. This information should then be used to study some of the problems mentioned at the beginning of the paper. For example to what extent can speed be increased before meeting driver capability limits. What would be the value of a reversible operator's workplace in viewing, or improved control. To what extent would automatic operator aids or automatic steering control aid the driver and enable him to either work faster or improve the control of other functions. Clearly with the tractor used so ubiquitously it will be impossible to be too precise on the man's task or advantageous developments. However, it should be possible to use these task analysis data to synthesise tractor operation so that the options above may be studied and it may also be possible to use it to look at the rather wider aspects of tractor design. The performance of many of these task elements will probably be limited by the environment and this is another reason for quantifying the man's work and those factors which affect it.

6 Acknowledgement

This review is largely based on the work of others. The author is therefore particularly grateful to the researchers whose conclusions are included and particularly to the many colleagues at NIAE on behalf of whom this information is being reviewed.

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BOOK REVIEWS *(see also page 99)*

Profitable Farm Mechanisation

THE third edition of Claude Culpin's *Profitable Farm Mechanisation* has recently been issued. This well known work aims to provide information and guidance on some of the main factors concerned with economic mechanisation and is intended for farmers, those concerned with the supply of farm machinery, including advisers, teachers and students. An attempt has been made to bring all basic information up to date and to present it in such a way that the effects of further changes can be estimated. The book is intended to be complementary to the author's *Farm Machinery* which gives further information about individual farm machines and their characteristics.

BAM

Profitable Farm Mechanisation, Third Edition.
Claude Culpin.
Crosby, Lockwood, Staples, London.
Price: £7.95 net.

Soil Properties and Behaviour

THE principle aim of this book is to present an insight into the actual mechanisms governing the deformation behaviour of soil in different moisture states. The authors draw widely from the fields of agricultural soil science and civil engineering soil mechanics to give an integrated text describing soil behaviour when subjected to external stresses imposed by man and climate such loading and shear, wetting and drying and freezing and thawing.

The introductory chapters give clear coverage of the nature of soils and types of clay mineral, the surface activity and water interactions of the clay fraction and the build up and packing of the mechanical constituents in the form of structural units. The mechanisms of soil water retention and movement are discussed together with those of swelling and shrinkage and consolidation and compression. Sight is never lost of the field requirements, and direct and indirect methods for measuring water content and suction, the problems of estimating swelling and heave and the limitations of consolidation theory are considered.

The concept of yield and failure and the strength theories describing them in soils are examined, with great emphasis being placed on the need for compatibility between the strength parameters measured and the particular soil failure theory used. The usefulness and limitations of Mohr – Coulomb theory is fully discussed in both granular and cohesive soils, using the concept of sliding and interlocking friction for granular soils. Very clear comprehensive coverage is given to the mechanisms of soil strength development in cohesive soils, including aspects such as pore pressure in saturated and unsaturated soils and inter particle and structural bonds.

The final chapter describes the freezing process in both fine and coarse textured soils and discusses methods for estimating the frost penetration depth and the potential soil heave.

This book is of no value to the person who is looking for an "off the peg" soil mechanics solution to his field problem, and this is not its aim. It does however, provide, in a very well set out and easy to read way, a very clear description, backed up with well chosen references, of the mechanisms governing soil deformation behaviour. This solid basic information enables the reader to select and develop the most appropriate model and theory for his particular problem. Imperial units are used throughout the text. A very useful text for those involved in agricultural soil mechanics and related fields.

GS

Soil Properties and Behaviour.
Raymond N Yong and Benno P Warkentin.
Publishers: Elseyier Scientific Publishing Co. Amsterdam. 1975.
Price: Dfl. 95.00 £17.00.

Psychological aspects of agricultural ergonomics

by Ronald Easterby BEE MSc CEng

1 Introduction

AGRICULTURE has become part of our industrialised society. The increasing mechanisation of the land has changed the role of the farm worker in ways which parallel the industrialisation of the 19th century cottage industries of England. Industrialisation here took the form of firstly replacing the manual tasks with machine based tasks with the human providing the necessary power, and this in turn was followed by the modification of human participation by the use of steam power instead of human power.

This revolutionary process developed over the century of ascendancy of the steam engine, and was followed by its demise as the prime source of power for manufacture and transport, and its replacement by the electric motor and the internal combustion engine. These same processes which shaped the changes in manufacturing industry have at the same time been bringing about changes in agricultural work. The stationary steam engine in manufacture and the locomotive in transport were paralleled exactly by the steam traction engine in agriculture.

The engineering inventions of the agricultural engineer were motivated by the same principles as engineers working in other applied contexts – the improvement in the effectiveness of working by using machines optimally in conjunction with the workforce. Like all branches of technology, agricultural engineers concerned pushed their technology to its limits in an effort to reduce the human effort involved in agricultural processes – that which could not be achieved by machine was still dedicated to the operator of the machines.

In one sense however, the industrialisation of the farm is different from industrialisation of manufacture. Perhaps because of the rich variety and unpredictability of nature which overlays all the activities of the farm, massive economies of scale using the principles of mass production has not as yet been utilised extensively in farming. Equally, the systemetisation and the complex of interacting methods of control and information characteristic of many industrial systems is not apparent in agricultural operations.

2 Man and machine in agriculture

The reasons why it is important to dwell on the industrialisation process if the fact that the advent of machine has brought about great changes in the organisation of work and in addition has also modified radically some of the social fabric of the society into which machines have been introduced.

The machine modifies the tasks that we ask men to perform, makes new and different demands on their resources and energies, and requires them to modify their performance and the exercising of their skills. It changes the pattern of the working day and, especially in agriculture, it may modify their work pattern so that it changes and their relationships and interactions with other workers during both work and leisure time.

2.1 Man/machine performance

A man interacts with a machine in two ways – he may derive information from it by the use of displays and he may change the way the machine performs its functions by the use of controls.

This model of man machine interaction, which is the basic conceptual framework which the ergonomist uses, is fundamentally concerned with the exchange of information between a man and the machine he is controlling. The machine-display-man-control-machine loop enables us to analyse the way machines and men interact. The characteristics of the displays and control are thus as much a function of the characteristics of the man as they are of the machine with which they are associated.

The basic sensory processes of the man – visual, auditory and tactile – are the channels for deriving information on the machine's behaviour, and the hands and the feet are the output elements for activating controls to influence the performance of the machine. Linking the displayed input to output control actions is the operator's capacity to process information and hence perform the task.

But there is not a simple one-to-one logical correspondence between input and output as there is with machines. Firstly, there is a continuous variation in the information that the man derives from the machine displays and he is unable to simultaneously handle them all – he must share attention between them by alternately attending to one variable and then another. Secondly there is a finite time requires to assimilate a display change and react to it, and typically a reaction time could range from 0.2 of a second up to 1 second for more complex discriminations. Thus, display change and associated chain of responses cannot be simultaneous; the controller of a machine needs a set of strategies to be able to effectively overcome some of these inherent limitations of his own processing system. Indeed, given these limitations, it may seem surprising on the face of it that men can execute any control over machines at all.

But one key aspect of the organisation of the control of movement makes all the difference to performance. Each of the muscles controlling our bodily actions has its own private feed back path to the brain so that the orientation, force and current state of the limb segment is transmitted to the brain, without recourse to visual monitering, and we learn to rely on these cues from these kineasthetic senses the more experience the performance of the task. This increasing reliance on kinaesthetic information is a feature of all human motor activity – that associated with standing, walking, running, speaking and of course controlling and operating machines. Its advantage is of course that it frees the visual system to assimilate new information. While the current action is being executed it is being monitered by the kinaesthetic senses, and the visual sense is collecting new information in preparation for the future activity. The designer of a machine who neglects this important feature of human performance does so at his peril, especially if through this ignorance he makes it difficult for the operator to function using kinaesthetic cues. Sound machine design enhances the use of these cues thus enabling more accurate and efficient control of the machine process.

2.2 The skill of the operator

If we ask a group of people to operate a machine and observe closely their activity, one thing that is immediately apparent is the variety between individuals in terms of organisation, speed, accuracy and general proficiency. There are many different ways of operating a machine and the task of driving a tractor or operating a combine is not uniquely determined. The reason for this is of course the inherent flexibility of human performance. We define this flexibility to change, modify and successively improve performance as the development of a skill.

Skilled tasks involve goals or objectives and there are any number of alternative links between the starting point and the eventual goal. The more effective an operator is in achieving this goal, the more skill he is said to have developed.

In exercising his skill the operator of a farm machine involves a variety of psychological processes which add up to his total performance.

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Paper presented at the Autumn Conference of The Institution of Agricultural Engineers, held in The Conference Hall, National Agricultural Centre, Stoneleigh, Warwickshire, 14 October 1975.

- **Identification** — the perceiving of objects and cues in his operating environment and understanding their relevance to his current task.
- **Discrimination** — identifying the elements and cues in his current task and perceiving the differences between them.
- **Scaling** — assigning value to the information with which he is presented. Scaling may be simple ordinal (yes/no) or may be finely structured.
- **Integration** — assimilating information from a variety of sources and tying them together in some meaningful whole which is relevant to the current phase of the task.
- **Remembering** — using past information which he has stored in some form either the immediate past, or from previous experience of the same task.
- **Judgement** — weighing the different information and combining it.
- **Decision** — combination of judgements and commissioning a course of action.
- **Ordering** — arranging the temporal order in which actions are to be commissioned.
- **Timing and Co-ordination** — determining the exact points in time when actions should be initiated or terminated.
- **Monitoring** — collecting information to confirm that the actions and responses are as planned.
- **Anticipation** — planning future actions.

To a greater or lesser extent of course a machine can perform some of these functions, depending on the complexity of the technology which has been developed. But the contribution of the farm machine operator is his skill, which is the way he combines all these elements into an integrated activity. All of these attributes can be observed for instance in the simple task of using a scythe. It is not given to all of us to be able to even appear to use it effectively, let alone actually use it efficiently, and it serves as an excellent model for the abilities which the skilled man possesses and are potentially available when considering what to allow the man to contribute and which aspect of the operations to assign to the machine.

The user of the scythe observes the grass he is about to cut — and discriminates it from the objects he wishes to avoid. He scales it in terms of variables such as size, height, angle and density and then integrates in into a meaningful whole. He remembers, perhaps, a similar size, shape and weight of swathe which he has cut before, may determine some minor differences and then combine this into a judgement before he decides to commission the stroke. Having done this he orders the pattern of muscular activity and at the right point in time initiates the stroke. While in action he monitors it, meanwhile anticipating the next stroke by gathering new information. In short he possesses a skill — an ability which it is impossible to design into a machine.

3 Implications of human performance on machine design

By now it should be apparent that simply leaving the odd tasks that we cannot mechanise for the man to perform is a less than optimal solution for using men and machines in agriculture. The aim of the designer of agricultural machines should be to use the machine to enhance and extend the capabilities of the man rather than replace him. Once the key decisions on the principles of an operating mechanism have been taken, it is time to consider its relationship with the operator. The design of the display and control links must be evaluated so that they can enhance the basic psychological processes enumerated above.

3.1 Designing for identification and discrimination

We need well designed displays to enable ready identification and discrimination of the objects and cues needed for the task, including the different controls we provide for the operator. Size, shape and orientation of the control elements are all important cues for the operation of the machine. Legends, title and symbols are ways of reinforcing the identification and their design and standardisation is an important contribution of ergonomics to the design of efficient and safe machines.

3.2 Designing to facilitate scaling

In formulating judgements it is often necessary for the operator to assign a value to some variable associated with the operation of the machine — speed, size, clearance, temperature, tolerance. The value required may be simply ordinal — is it bigger or is it smaller or alternatively is it within a given range? More complex possibilities require that the value must be determined with specified accuracy along a continuous range.

In all these instances, consideration of why the operator needs the information is the paramount design principle. If he needs a simple yes/no decision then a simple indicator suffices. If he needs simple numerical values then a straight numerical indication with its speed of assimilation is the optimum. If, on the other hand continuous quantification is needed, then an indicator design with due regard to the accuracy required, the accuracy of the data provided by the machine and accuracy with which the operator can determine the reading must all be part of the design process.

3.3 Designing to facilitate integration

At the level of facilitating integration of input information, the spatial ordering of the display is relevant. The way in which the machine designer chooses to disperse the information on the machine fascia can influence the ability of the operator to assimilate such information.

Equally important is the orderly and well structured grouping of control elements in terms of function, frequency of use, relative importance and sequence of use. To achieve this requires a thorough analysis of the task and some effort at compromise between the optimum location and disposition based on the mechanism, and the competing demands of optimum ergonomic requirements.

The grouping and association of display elements based on these principles of function, frequency priority on sequence must all be evaluated, but since they cannot all be simultaneously satisfied, some delicate compromises are often necessary. As in all design, the skill of the designer is in achieving this compromise. The purpose of the psychological notions enunciated here is to ensure sufficiently well articulated design principles are stated to support the basic data on human performance.

3.4 Designing to facilitate memory

In designing a machine we often wish to refer to elements of the machine or setting position of the control using codes, numbers or mnemonics. Our ability to reproduce these codes when performing the task by remembering them accurately when transferring from one element of the task to another can be influenced by the choice of code. Numbers are more readily retrieved than letters which are random; meaningful series of letters are more accurately retrieved than random series and the characters at the beginning and ends of codes are more accurately recalled than those in the sequence for instance. Once the series begins to exceed 5 or 6 then these errors start to manifest themselves because we have exceeded the short term memory capacity of the operator.

The way information is presented to the operator can also facilitate his memory — more particularly the immediate or short term memory. Our memory at this level is fairly volatile and short lived — we can only retain and accurately recall around seven items (numbers, letters, codes) within a space of about ten seconds. The way such information, which might be used to determine settings of levers and controls, is arranged, can radically influence its accurate recall. Grouping and ordering of sequences, the layout of tables and codes and the associated labelling of controls in a compatible way are the key psychological principles here.

At the level of judgement, and also memory along a longer time scale than the short term mentioned above, there are built into every operator's experience stereotypes or expectations about machine controls, especially with regard to the expected motion which results from actuating machine controls — clockwise to increase or to move right for example. These

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stereotypes have no intrinsic psychological basis since we are not born with them built in to our perception of the world. But they are well established by exposure to a wide variety of machines and it is possible to actually measure the strength of these stereotypes for various control actions amongst the user population. There are of course significant implications here for the standardisation of these control relations since there needs to be compatibility within a machine and between machines so that there is good learning transfer when the operator moves from one machine to another.

If you are tempted to suggest that it is of no significance and that the operator will learn to overcome any shortcomings in this regard, it is as well to know that under stress, there is a tendency to revert to the simplest interpretation and to align with a previously developed stereotype.

3.5 Designing to facilitate judgement and decision

No specific detailing of display and control information can be related to judgement and decision; the issue is an interactive one which rests on the proposition that the relevant information is made available and that, as far as possible, all information irrelevant to the current decision is suppressed. Since decision results in action however, it is most important that the operator receives useful feedback on the consequences of his actions. Not only is visual feedback of information through associated changes in displayed variables important, but tactile feedback can be useful with limiting and detent positions of controls being concisely articulated in the mechanism. The role of the auditory feedback also must not be under-estimated as an aid to the operator in confirming that he has made the correct decision and initiated the correct sequence of actions.

3.6 Designing to facilitate ordering and timing

The spatial layout of the operator's workspace must reflect, in some way, the ordering of the different control elements used in the task. Widely dispersed elements lead to unnecessary psychological load (as well as the physical effort involved) in the location and discrimination between the various controls. This extra load can be using up reserves of attention which should be devoted to more important aspects of controlling and monitoring the machine. Further, the proper association between a control and its related display variable can usefully reduce the demands on the operator. It is not simply a question of creating a nice easy job — it is attempting to conserve the psychological resources for the real business of operating the machine and coping with disturbances generated outside the man machine environment.

The advent of hydraulically controlled mechanisms on agricultural machinery has greatly simplified the problem of arranging controls, since the control lever of handwheel no longer has to be connected directly to the appropriate shaft. This freedom of choice means that the designer must consider carefully which are the best associations of control functions.

Massed banks of identical hydraulic valve control levers assuming a variety of functions equally leads to difficulties of identification and discrimination, which in turn will lead to errors of commission no matter how skilled the operator may be.

The stereotypes which relate the movement of controls to associated display responses are important here too in aiding the operator to order in time, his control movements. By extension of this principle the sensitivity of the machine's response to control movements and the delays and lags inherent in the control mechanisms can also radically influence the accuracy and the stability of the control exercised over continuous functions in machine operation.

Finally, continuous control operations, which are common in agricultural machines, must provide the ability for advance information to the operator. He must have information on the likely future value of variables by having indicators which enable him to assess rates of change as well as the current state of any key variables. The design of the machine must not load him so extensively requiring him to do so many things at once that he has no spare capacity to devote to predicting future machine performance.

5 Safety and performance

The growth of the use of machinery in agriculture has been primarily motivated by the need for improvements in the productivity of the land. The use of the machine vastly increases the power available to the farmer to cultivate the soil and manage his stock. This increased power is bought at the cost of increased complexity of operations both in operating the machines and maintaining them.

However there is a further charge on the use of machinery, and that is the risks that it creates for those who operate them.

Errors may be initiated by the machine or the man and in turn may damage the machine, the man or the produce (or animals). Now although in any given instance it is possible to attribute the mistake to 'operator error' the reasons for such error may derive from the manner in which the machine was being operated at the time. This in turn may not in many instances be directly the fault of the individual involved, but may be the consequence of being obliged to operate the machine in a particular way because of its design.

Thus, all the foregoing discussion on human performance and the influence that it should have on design is pertinent to the safe operation of the machine. In discussing these features, repeated reference has been made to either speed or accuracy of performance. Speed of performance is in a direct sense related to the productivity of the machine or process, while accuracy is predominantly associated with the quality. But they are not simple separable variables, since the operator may often trade one for the other by either performing the task slowly but well, or quickly but less accurately.

How he achieves this trade off is a delicate balance between his goals and the *perceived risks* in increasing his speed. Notice here the deliberate use of the term *perceived risk*. It is how dangerous the operator thinks the situation is in a particular situation that counts, not how dangerous it may be in actuality and the difficulty is that in most instances he perceives risks as rather less dangerous than they actually are, and behaves on this assumption.

Therefore in attempting to design for safety, the agricultural machine designer must allow, in a conservative manner, for the risks that operators may choose to make when operating machines.

The rate at which individual errors occur is never high, eg wrong lever setting might be made one in fifty settings. Many of these errors are of course corrected — the only loss is in the extra time required to correct the mistake. But the feedback in a proper way of display information confirming the correct settings and adjustments of controls is therefore paramount — it facilitates learning *and* it allows for correction of error.

In summary then, what is being suggested is that detailed attention to many psychological aspects of designing machines can improve the accuracy of performance and the facility with which operators acquire the skill to control their machines free of errors and mistakes. Good ergonomic design can lead to a reduction of error which in turn not only leads to improved efficiency but also to enhanced standards of safety.

The relationship of livestock to human beings and machines on the farm

by Martin F Seabrook BSc PhD

I Objectives

IN this present conference one can consider that this paper should deal with the relationship of livestock to human beings and machines on the farm in order to improve efficiency and safety. The first burning issue which will probably have been considered elsewhere is what does one mean by efficiency? Does one mean increased output with similar or lower inputs, if so are we considering efficiency for the workers, the employers' or Society's point of view. Should one really have been considering "The future for operator satisfaction and safety in the agricultural industry"?

(a) What is the object of operator efficiency?

Without the author wishing to be considered a Luddite or a revolutionary it is still necessary for this paper to question the degree to which efficiency is a goal. Operator safety obviously must be an unquestioned goal. Efficiency may be measured in simple or complex terms; in the context of this paper cows per man or gallons of milk per man can be considered as useful ratios for measuring efficiency; and it is easy to set out ways of measuring the cows per man ratio. In other words it is possible to design milking systems with simple repetitive tasks and men working in technically efficient work environments. Similarly in the arable context one can design bigger and faster machines taking much of the skill and operator decision making out of the work. It is important here to consider two other areas that have been the focus of efficient and technically competent planning, ie town planning and factory design. The former has given us tower blocks of flats, the latter the production line process; both technically efficient environments, well planned and safe. The results of these are only too obvious to sociologists, psychologists and the like.

Baby battering
Neurotic mothers
Neurotic children unable to play outside
Juvenile delinquency
Football hooliganism
Boring jobs
Mind destroying repetitive work
A lack of purpose to life

All this is emotive material and the resultant of complex interactions and not as simplistic as shown. However, the underlying philosophy is correct, ie, that town planners or factory designers have failed to consider the human factors involved, the invididual nature of man and his basic desires. Thus while they have designed efficient systems for optimising people per square foot or production per day they may have failed to consider what the individual person wants.

(b) Who is "efficiency" for?

There is always a conflict between short term goals and long term goals. In our present situation when forced to complete in a difficult trade situation and where the cost of our exports is critical it is perhaps not an appropriate time to raise philosophical issues. This paper thus merely sets out a few questions.

(i) Does the individual goal of the farmer conflict with society's goals? (But what are society's goals?).
(ii) How can increasing output per man be reconciled with high unemployment levels?
(iii) Does efficiency mean that profit for the entrepreneur is received at the expense of society who has to support the unemployed?
(iv) Are there incompatible objectives between economic efficiency and job satisfaction for the worker?
(v) Is one large tractor really more efficient in terms of society's goals than two smaller ones?
(vi) What role has intermediate technology in British Agriculture?
(vii) Can we go on building and creating more and more consumer goods?

II Man/management relationships

Management systems in agriculture have attracted much interest recently (Lloyd and Armstrong 1975) and more is becoming known of the 'man' in agriculture (eg Seabrook 1975a). Less is perhaps known about how the individual worker perceives the actions and attitudes of management although it has been shown (Seabrook 1975a) that individual workers do perceive management actions and attitudes differently.

It is not the brief of this paper other than to superficially discuss this relationship, but since it interacts with everything that occurs on the farm, it must be discussed.

There is growing evidence that agricultural workers are not as satisfied with their working environment and management attitudes as many people would like to think. Certainly farmer attitudes to workers will have to be adapted to meet the growing demands of a more highly educated work force.

The personnel management process will be modified by the worker's acquired skill and attitudes as well as by background

Table 1

Factor	*Average order of priority*
Having more freedom to choose the actual hours worked	6
Improved work methods	4
Obtaining a greater feeling of satisfaction from doing his job well	1
Having more control over the pace of work	8
Receiving more pay	5
Having achievements recognised personal thanks	2
Being more involved in target setting	10
More chance to have responsibility and make decisions	3
Receiving more information on farm's policies	9
Better housing	7

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factors such as personality, age, family, location and socio-cultural factors. These will all influence a worker's view of his job, the management and the function of his work. The personnel management process then cannot be considered in relation to the work identity, background and personality of the individual workers in the fair situation, as has been done by Lloyd & Armstrong (1975).

A group of workers were asked to rate the priority of various changes they wanted to see in their job in the future. These workers included a wide range of skilled men. While there was considerable variation in priorities for different workers the general trend was as shown in table 1.

In the same study people were asked to indicate reasons for getting satisfaction from job and reasons for not getting satisfaction. The results are summarised below, and confirm findings by Jarvis (1974).

Factors in feeling good about the work

"The good job I had done was appreciated".
"I felt I was achieving something".
"I felt a sense of responsibility".
"Supervision was kept to the minimum".
"I enjoyed the work".
"Management understood my work problems".

Factors in feeling bad about the work

"Management didn't try to understand my work problems".
"No-one appreciated the good job I had done".
"There was too much supervision".
"I had no responsibility".
"I felt I was wasting my time".

(a) The process of personnel management

Figure 1 attempts to put the concept of personnel management into the context of this paper indicating the derivation of effective work. Some of the processes are summarised in table 2.

(b) The workers view?

Management is not simple as the process may be viewed differently by the worker, there may be an essential conflict between 'management view' and 'workers' view'.

The basic assumption of current management thinking is that work provides many benefits in personal development for the worker. It could equally well be shown that work provides few benefits to workers, other than monetary gain, and that the concept of 'job enrichment' is merely a management tool for increasing work output as cheaply as possible.

To many workers, work is merely a means of earning money in order to enjoy their 'extra-work life'. There is nothing wrong in this. To these workers, more money and more leisure are effective motivations and more beneficial than 'job enrichment'. Similarly, many job situations provide little opportunity for the worker to control the *pace* of work. The pace of work may be too rapid for many workers and imposing too great a pressure on them. Thus, instead of 'job enrichment' we should perhaps be considering 'job shortening' ie working days and fewer hours per day.

The concepts behind current thinking on personnel management are perhaps too dogmatic and fail to take into account the individual and varying needs and aspirations of workers. There is no universalistic answer; different people need different things. Different workers seek to obtain different rewards from their work (eg the introvert person lacking self-confidence will be unmotivated by being given a position of considerable responsibility. He will feel constantly "out of his depth").

Workers are individuals with individual aspirations brought about by:

(a) Personality
(b) Age
(c) Experience
(d) Family needs and family aspirations
(e) Group pressures, ideas of associates
(f) Location
(g) Education

There is thus a need to examine and analyse what the individual wants from the job, ie it may be solely money (there is nothing wrong with this!). Management should as far as possible meet these needs and hence motivate the worker. What is important to one worker may be irrelevant and unimportant to another. Without some knowledge of the individual importance of these factors to individual workers, proper motivation cannot be provided.

Fig 1 The derivation of effective performance.

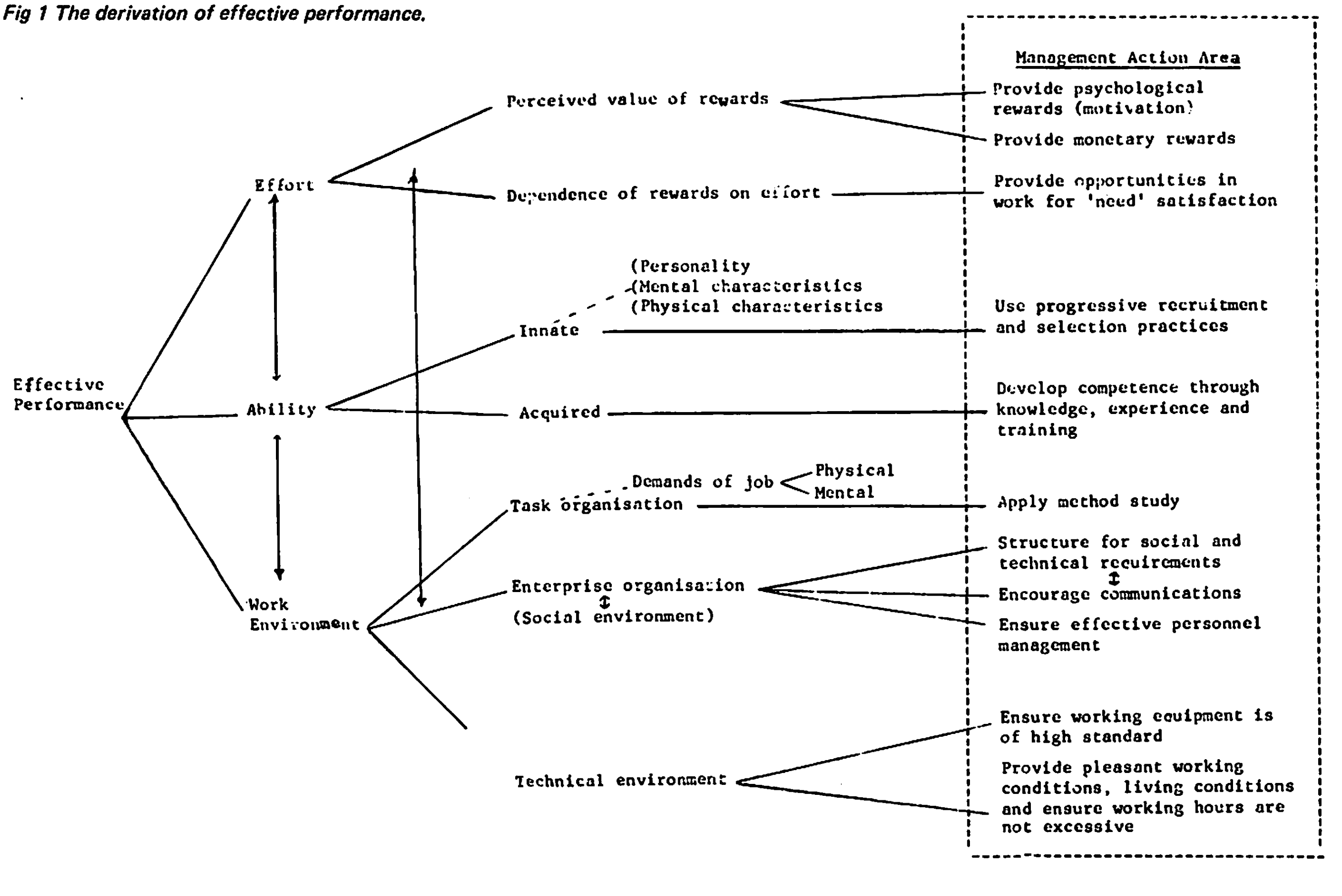

Table 2 The process of personnel management

1 Communications:

(a) worker must have knowledge of aims of the business,
(b) " " " information to do job well,
(c) " " pass on information to supervisors,
(d) " " feel action is taken on information he gives.

2 Personal Relationships:

(a) teamwork,
(b) close relationship with supervisors,
(c) help and co-operate with colleagues,
(d) worker must feel he can influence his workplace activities, methods and standards.

3 Control:

(a) worker must feel he can control his work and methods,
(b) worker must have influence over others whose job affects his work,
(c) group consultation on job methods,
(d) checking of work standards.

4 Motivation:

(a) workers efforts must be appreciated,
(b) security in job,
(c) job status,
(d) sense of achievement from job,
(e) opportunity to set own work standards.

5 Leadership:

(a) worker must have confidence in top management/immediate supervisors,
(b) management must try to understand work problems,
(c) " " value and invite opinions on all aspects of the work.

6 Decision making:

(a) decisions should be made on all levels — worker must have opportunity to make decision,
(b) management must be aware of work problems when it makes decisions,
(c) workers ideas must influence decisions made.

7 Work targets:

(a) workers must be involved in setting targets,
(b) targets must be clearly defined,
(c) targets must be acceptable.

8 Performance standards:

(a) ensure job cannot be improved by using new methods,
(b) avoid waste,
(c) ensure correct training given,
(d) ensure jobs as a whole well organised.

If low self-involvement (investment) at work allows workers to invest and be involved outside work, then there is no point in altering work for that worker. If, however, the individual worker finds low self-involvement at work impairs his ability and motivation to invest himself outside work, then something must be done about the work situation of that worker, either by job enrichment or a change of job.

In order to assess those factors sought by agricultural workers from their work, Seabrook (1974) has developed an individual motivation questionnaire which enables an individual motivation profile to be drawn up for each worker. From this it has been possible to draw up a generalised model of worker objectives *(see foot of page).*

(c) Quality

Rather than efficiency we should perhaps use the word quality which covers a wider interaction than efficiency, ie we need to consider:

The quality of the worker.
The quality of management.
The quality of relationships.
The quality of the working environment.

Now these are aspects on which it is difficult to be objective about however they are more likely to be of use in the 1980's than the efficiency of the working environment etc.

These pieces of evidence indicate that the man/management system is vital in increasing the quality of the working environment, with the indirect pay off of more output.

III Man/animal relationships

The author has already shown (Seabrook 1975) the importance of a good man/animal relationship in the milk production process and a generalised model of the importance of the relationship from the study are shown below:

(1) Those cowmen who achieved higher job satisfaction achieved higher yields per cow.
(2) Individual cowmen sought individual and different achievements from their work, were motivated by different factors and had different aspirations.
(3) There was no correlation between herd yield and the age and status of the cowmen.
(4) There was an apparent correlation between herd yield and the personality of the cowmen (Seabrook 1973). The confident introvert tending to achieve higher yields (with identical inputs and conditions) *(fig 2).*
(5) A generalised model of the influence of the cowman personality was devised:

(a) a tendency to introversion and confidence — high achievement.
(b) a tendency to introversion and non-confidence — lower achievement.
(c) a tendency to extroversion and confidence — average achievement.

(6) Important Times for Developing Relationships Between Cows and Cowman:

Examination of heifer behaviour does show that the heifers appear more settled on the higher yielding herd compared with the lower yielding herd. The heifers come readily into

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Factor highly scored on average

– Involvement in target setting
– Being given more responsibility
– A more varied job
– Improvement in working methods
– Better relationships and communication with supervisors
– A greater sense of achievement
– Receiving more recognition for achievements

Factor not consistently scored by all

– Security from redundancy
– Working shorter hours
– A greater feeling of working in a team

Factor consistently scored by all

– Control over the pace of work
– Receiving more money

Factor lowly scored on average

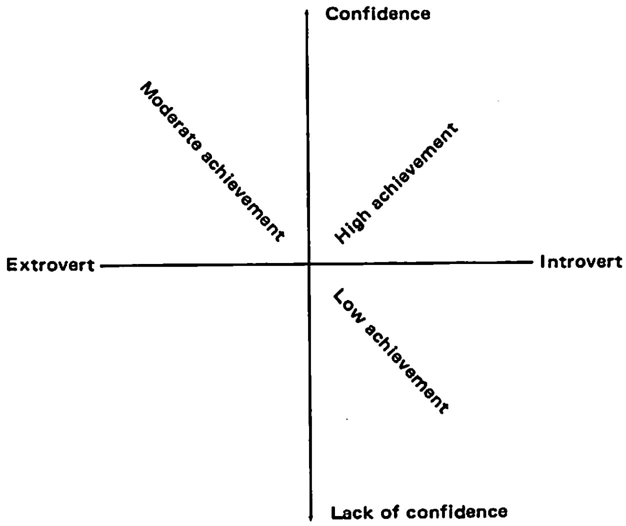


Fig 2

the parlour and stood quietly. This may suggest the relationship is established early in the animal's life. Since all the heifers on both herds are reared at a central rearing unit, the only time they receive different treatment is when they come into the herds a month or so before calving. This may indicate the time around calving as being a critical period for establishing the relationship. There is further evidence to suggest this critical period. If there is a change of cowman, there is little effect on herd yield until calving occurs on the units. It is well known that the lactation yield is affected by the peak yield soon after calving. The cow has a certain potential and providing "stable" conditions the cowman may be able to trap this potential fully.

The importance of this critical period around calvings indicates the need for the cowman to treat the cows sympathetically at this time, as this seems to increase the relationship. Confidence in handling the cow will also increase this relationship. It is suggested that the personality of the cowman is likely to influence his actions at this critical time. If "stable" conditions are not set up, then it is probable that adrenalin levels in the cows are higher and this inhibits milk let down and reduces the peak yield after calving. The cow may associate the cowman with her calf and if she can do this, then this will increase the relationship. Ewes at the time of parturition are receptive to new odours and contacts, so perhaps, is the cow. It is thus possible that if the cow receives favourable treatment, she will recognise that smell of the man for a long time and react advantageously to him. The cowman in the higher yield herd talked to his heifers at calving and when in the parlour and this seems to encourage them to be placid. The cows seem to respond to the tone of voice of the cowman on the higher yielding herd and do as he tells them. This work on behaviour patterns has clearly indicated strong differences in cow and cowman behaviour between the two herds. From these results some general patterns emerge, ie with a better relationship:

(a) Cows come more easily into collecting yard.
(b) Cows come more easily into parlour.
(c) The cowman talks to the cows.
(d) The cows do not move away when approached by the cowman.
(e) Heifers do not come into the parlour last.
(f) The cows come up to the cowman when out in field.
(g) The cows do not appear restless when in parlour.

When these were applied to a number of other herds it was possible to show a trend of increasing yields with an increasing close relationship between the cows and cowman.

(7) Relevance of conclusions to commercial dairying:

(a) The personality of the cowman is important, and if all other factors are equal, the confident introvert is likely to achieve the best results.
(b) If a "good" relationship exists between cows and cowman, higher yields are likely.
(c) Treatment of cows prior to milking is important.
(d) The relationship man/cow can be influenced by:

(a) Handling of cow prior to calving.
(b) Handling of cow just after calving.
(c) Handling of cow prior to milking.

(e) It seems likely that cows can sense a lack of confidence in their cowman.

(a) Optimum number of cows per man

One cannot fail to consider this aspect here, particularly as the ratio of cows per man is one so often questioned. There are a number of ways assessing the optimum ratio including:

(1) The experiences and feelings of management.
(2) Results from research programmes.
(3) Increasing the ratio until the system breaks.
(4) Guess work.
(5) Workers experiences and feelings.

Recently the author considered the last method .and questioned an homogenous group of cowmen working on various one-man units over the country. They were all working on herringbone parlour/cubical (kennel) housing systems where silage was fed. These people were asked how many cows they would be prepared to milk on their present system (given any slight modifications). Their answers were related to their present milking herd and their personality. The results are set out in fig 3.

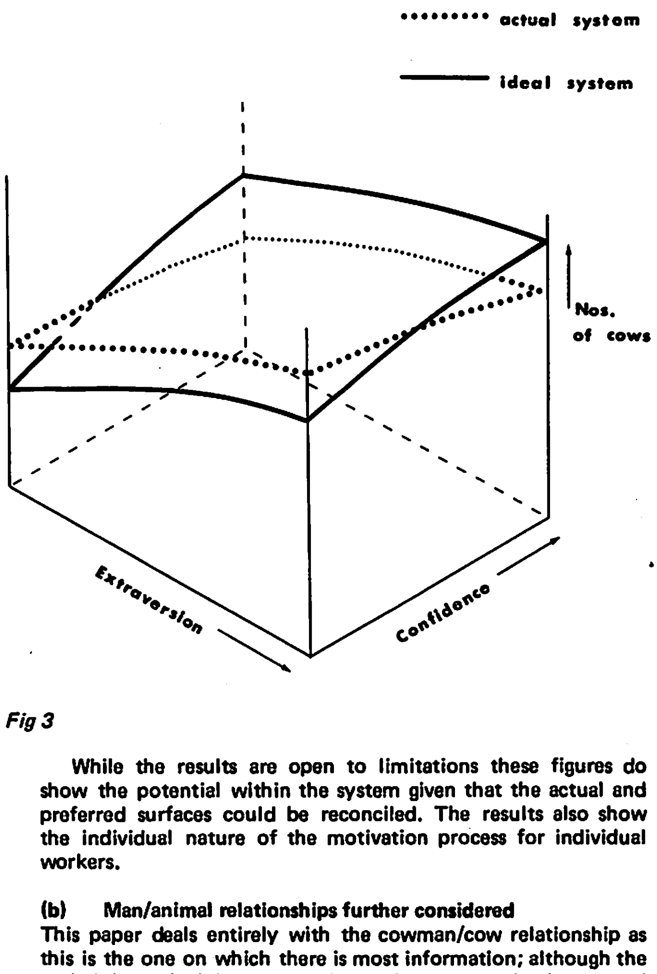


Fig 3

While the results are open to limitations these figures do show the potential within the system given that the actual and preferred surfaces could be reconciled. The results also show the individual nature of the motivation process for individual workers.

(b) Man/animal relationships further considered

This paper deals entirely with the cowman/cow relationship as this is the one on which there is most information; although the underlying principles are consistant from one animal type and animal system to another.

In earlier work the author had stressed the need for the man/

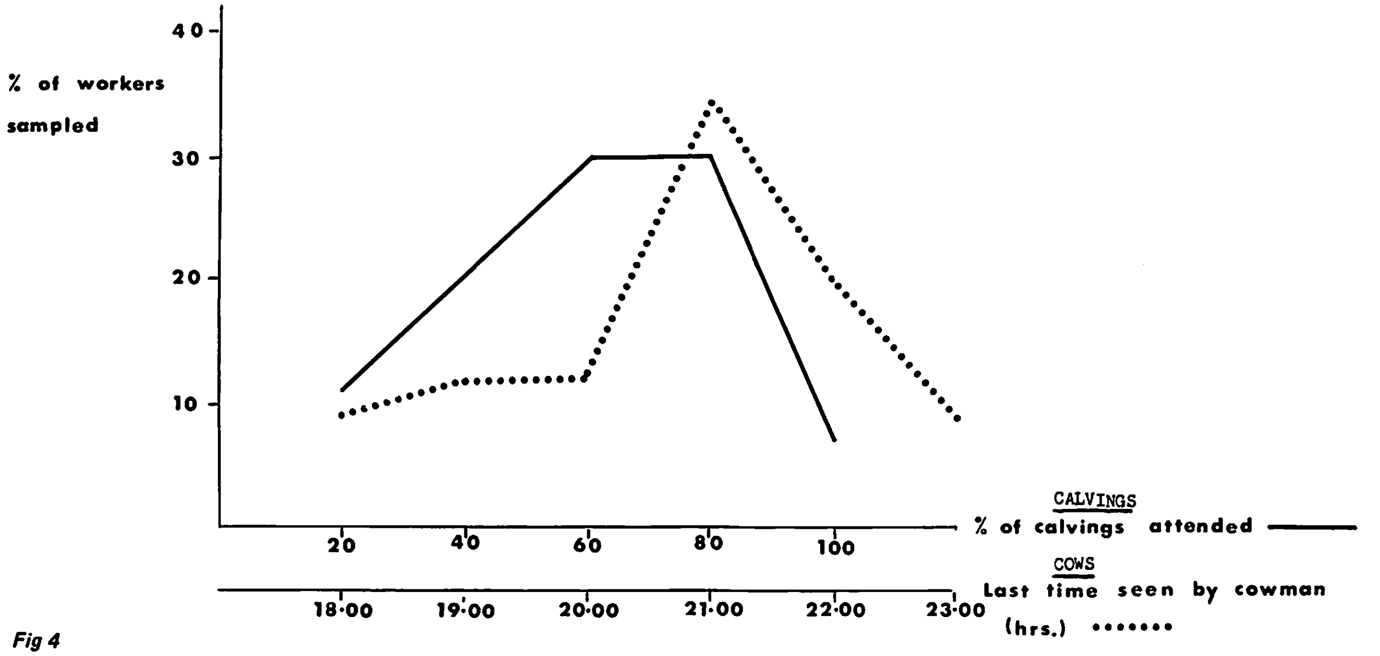


Fig 4

animal relationships to be built up at calving time. Esslemont (1973) has indicated the need to see cows late in the evening to observe oestrus. Fig 4 shows results from a recent survey by the author, that this is not being achieved in practice for all herds. The results came from a recent survey by the author.

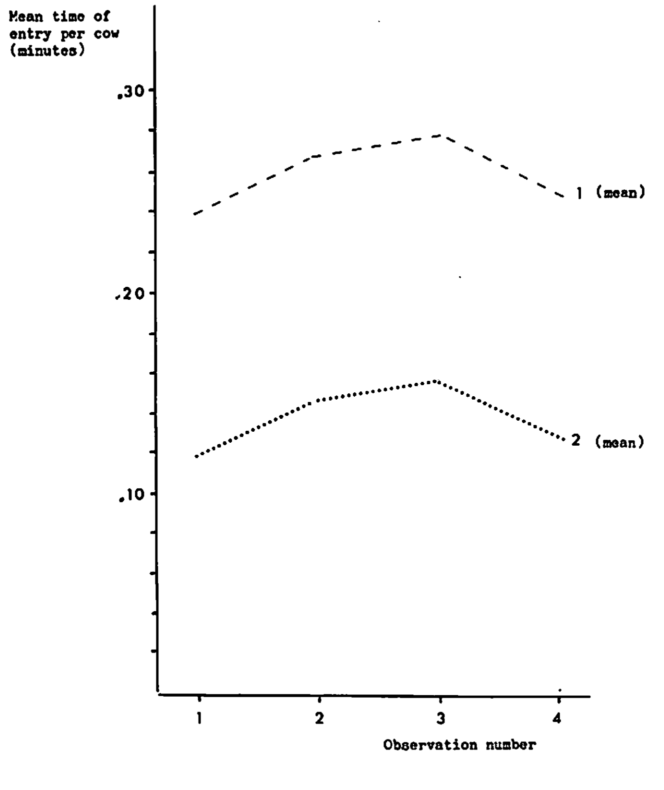
IV Animal/machine relationship

This is a somewhat difficult subject to discuss particularly as what information there is consists at two levels, ie,

(a) Studies of stocking density ie birds
(b) Subjective animal behaviour studies.

In essence the majority of livestock have little need to develop a relationship with inanimate machines and if they do eg with the milking parlour their behaviour is modified by the man/animal relationship. (Fig 5); it will also be confounded by their relationship with other animate objects, thus, for example, speed and safety of entry of cows into a rotary parlour is a function of the cow's relationship with the man in the pit.

Fig 5 Mean times for cows to enter the parlour.



It has been suggested that cows have personality traits not disimilar to humans and thus probably do react to incriminate machines; however, all that can be discussed is how this action is seen by man. Thus the author decided to look at aspects which influenced how the animal related to a machine but as perceived by man.

This in simpler terms means what improvements and modifications needed to be made to the machine (ie parlour and collecting yard) and what factors caused stress to the cows within that system.

The logical step from this would be that if these were modified or prevented from occuring then the animals would be in a less stressed state and they and the cowman would be happier.

Improvements cowmen wanted to see (in order of priority)

(1) Modified feeding hoppers in parlour.
(2) AI stalls/means of diverting cows on leaving parlour.
(3) Modifications to collecting yard.
(4) Improvement of cleaning system.
(5) Faster milk transfer.

Noises within parlour causing upset to cows (in order of frequency of mention)

(1) Strangers.
(2) Loud talking.
(3) Rain on roof.
(4) Dogs.
(5) Football on radio.

V Conclusions

What can be done to link these factors and the comments about safety and efficiency? Firstly it is necessary to involve in any management consideration the following points:

(a) Personality of workers.
(b) Short term objectives of worker within work.
(c) Long term objectives of worker within work.
(d) Short term objectives of worker outside work.
(e) Long term objectives of worker outside work.
(f) Profile of the ideal worker for the situation.

Secondly it is necessary to install into any new system the best features of the old, eg if installing a rotary parlour it is necessary to consider such things as how to develop the man/animal relationship. Included in this is the establishment of sub-goals which exist in less advanced systems.

Thirdly to establish within the tasks the opportunities for job satisfaction, sense of achievement, chance to develop relationships and to have responsibility.

→ *foot page 120*

Edited summary of discussion

Morning session

P Wakeford (Electricity Council) expressed interest in Mr Dempsey's comment that he had not heard of dust explosion in agriculture and suggested that the grinding processes employed on farms produced dust of a coarser grade than that which is critical for explosion. He suggested that it would be desirable for farmers to take up maintenance contracts especially where dust is concerned. He wondered whether in such cases any reduction in insurance premiums could be obtained.

Mr Dempsey agreed that coarser grades of material tended to be produced in agriculture and readily accepted the principle of maintenance contracts but regretted that in his experience insurance companies took a broad view when determining premiums and did not take detailed account of the risks involved and the level of precautions taken.

D P T Rich (BAGMA) suggested that manufacturers will presumably pay attention to Section 6 of the Act when introducing new machinery. This should lead to improvements in instruction books where these are at present deficient. He wondered how Section 6 would apply to dealers in second hand machines and to auctions and private sales, and put the question, "To what extent can the disclaimer be invoked?".

Mr Weeks stated that second hand and auction machinery is affected in exactly the same way as new machines. The supplier is in each case responsible for ensuring that instruction for safe use is passed on to the purchaser. In the case of old machinery, where for example the instructions never existed or are now lost, the phrase "As far as is reasonably practical" may be invoked. The dealer should, however, pass on his knowledge of the machine. It may be that for simple machinery such as a plough, verbal advice would be satisfactory. For the supplier to be absolved from his responsibilities he must obtain from the purchaser an undertaking in writing that the latter will accept responsibility for the safe operation of the equipment. This is particularly applicable when part only of the machine is supplied.

R A Jossaume (dealer) commented that the situation often arises, when dealers' staff are working on a farm, for assistance to be given by farm staff. In such a situation who is responsible for the safe working conditions of the farm staff.

Mr Weeks replied that the farmer is at all times responsible for his own employees.

J V Fox (Bomford & Evershed Ltd) Mr Klinner has quite correctly stated that different considerations apply to the design of safety guards for hedge trimming and scrub clearing mechanisms. One has to consider, on the one hand, the variations in height and angle of the cutting mechanism and, on the other hand, the assortment of rubbish normally encountered in hedges and one can readily appreciate the problems. On top of this, the variations of different rotation and the dual purpose grass and hedge cutting machines serve only to make the problem more complex.

While the problems are considerable they are not insurmountable. The guard location in relation to the direction of rotation and the head position is critical as is the design of the guards to minimise the risk from wire etc.

Provided the guards are designed correctly the most suitable position for the cutting unit, whatever the rotation, is in line with the tractor wheels. In this position the cowling will give the maximum protection to the operator. He can see the type of finish he is achieving and, more important, he can see what is about to be cut.

Reverse rotation (forward acting flail) will normally give a better finish than forward rotation flails. However, when tackling larger material it is necessary to have the front of the cowl open to allow access. In this case it is impossible to guard with reverse rotation and forward rotation must be used. Whatever the rotation the guards must cover material thrown by the upward moving flail. With forward rotation it will be the rear of the cowl and with reverse rotation it will be the front of the cowl. It should be noted that the material thrown includes assorted rubbish and wire as well as the wood chips.

By far the most dangerous material to deal with is wire. It can be caught in the rotor very easily and at over 100 miles/h peripheral speed small parts can be sheared off by a badly designed guard and ejected in *any* direction. The edges of the guards must be rounded to prevent any shearing action. However, by deliberately designing a shearing edge inside the cowl we have found that this together with the round edges of the guards effectively lowers the angle of trajectory of any wire ejected. The risk from wire is therefore minimised. An interesting phenemenon arising from our tests is the importance of the roller on the rear of the cowl. This roller normally acts as a beater bar when hedge trimming and maintains the height of cut when mowing. Without the roller the tail of any wire caught in the rotor tended to be longer. This resulted in pieces of wire extending past the guards and being ejected at almost any angle. It is essential therefore to retain the wire close to the rotor over as long as arc as possible.

With the upward moving flails guarded the next area to cover is deflected material. While the amount deflected from parts of the hedge and the tractor will be relatively small we feel it is essential to protect the driver with a wire mesh. At first sight mesh of 3 mm material on a 25 x 50 mm grid may appear ineffectual but one only has to try and throw relatively small pieces of material through it to discover how good it really is.

It is worth remembering that no matter how good the guarding is there is no substitute for eliminating the hazards at source. Inspect the hedge before commencing your cut.

Finally, as a manufacturer or rotary hedge cutters for some years we have a fairly wide experience on guarding and we are willing to co-operate with any company which feels that they could benefit from this experience.

W Klinner expressed his appreciation of Mr Fox's observations and emphasised that the final defence for the driver is the tractor cab screening. This should be highly impact resistant and is typically made of polycarbonate material.

C V Brutey (NFU) commented on Mr Anstey's paper and made particular reference to the encouragement which needs to be given to engineers and trade bodies to participate actively in the work of international standardisation bodies. He believed that such participation was vitally important to the future successful incorporation of safety features in machinery and equipment to be marketed internationally.

J H W Wilder (John Wilder Engineering Ltd) pointed out that all British Standards are now closely linked to international standards and therefore by participating in British standards, British manufacturers are automatically aligning these with International Standards requirements.

J Morris (NCAE) suggested that a cost effective approach to safety was required in conjunction with the Act. Consideration should be given to the cost of accidents and the cost of their prevention. He asked in what proportions should money be spent on mechanical components (eg guards, on the education of the operator, or on the enforcement of the Act?). He wondered whether we knew enough about accidents to answer these questions.

Mr Weeks pointed out that the accident rate in agriculture, although not the highest, was amongst the industry's having what is generally regarded as a high accident rate. Manufacturers should be looking at their products from the view point of tho health and safety of the operator and the time to do so is clearly at the design stage. This is obviously preferable to waiting for legislation to decree that certain measures should have been taken. However, the competitive nature of business does not encourage a manufacturer "to go it alone" since he could easily price himself out of the market. For this reason, we must often await legislation as was the case for tractor cabs. The

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Act now suggests, however, that it is not sufficient for a manufacturer merely to satisfy specific legal requirements. He must ask himself what other steps he might reasonably take to protect the user. The education of the user is therefore clearly important and desirable but cannot provide the whole answer — if only for the reason that many people think themselves immune from accidents. Enforcement then will unfortunately be necessary but it is not the ideal situation and it is expensive.

Afternoon session

R H F Jeffes (NFU) asked Mr Matthews for further comments on the positioning of the tractor seat in relation to the controls in a similar manner to the work space layout in a car. He also wondered whether sufficient attention was being given to visibility from the tractor cab bearing in mind the hazards arising from reduced visibility, particularly in respect to children.

Mr Matthews replied that NIAE were not currently doing research on the lower seat position for tractors. He had merely referred to the lower seat position in connection with international standards work. At the present time such seats were only used on special purpose tractors (eg Unimog). He believed that development of the tractor seat would advance in conjunction with other developments, in and around the working area, which would include improvements to visibility. He mentioned that Mr Bottoms at NIAE was currently applying task analysis to the tractor which it was hoped would indicate what the driver needs to do and what minimum standards of visibility are required.

J V Fox asked Mr Matthews if the introduction into tractor cabs of controls for operating machinery fitted to the tractor was likely to result in the legal noise level being exceeded.

Mr Matthews did not anticipate problems in this respect. It was unlikely, he felt, that the 90 dB(A). limit would be exceeded since the noise level in most cabs was sufficiently below the legal limit to allow for such addenda.

W Klinner drew attention to the data presented in Mr Matthews' paper in which the female distress call was more than halved in intensity between good and bad tractor cabs. He expressed concern of the effect of all communications in the safety context and drew attention to the additional risk associated with the use of a fully suspended cab which can give rise to the operator having a false sense of security with potential harmful consequential effects.

J Matthews agreed with the above remarks and mentioned that as a result of the work on warning cries there was an indication that cabs could be fitted with some form of louvre, without any serious increase in the noise level within the cab. Communications might thus be improved, particularly in respect of links which the operator makes with the machine. He mentioned that the field evaluation of the NIAE suspended cab was largely being undertaken to investigate the effects that it may have on the operator during field use including the problem of providing a false sense of security.

A J Smith (NCAE) asked if there was any known relationship between accident occurrence to an individual and his psychological attitude, as expressed by Dr Seabrook, in terms of confidence and extroversion.

Mr Easterby pointed out, with agreement from Dr Seabrook, that it is not generally true to say that there is one section of the population or one type of person who is accident prone. It is predominently a matter of the level of stress pertaining at the time.

Dr Seabrook added that people who experience "job satisfaction" are known to cause less breakages and damage.

T Sherwen (consultant) again raised the question of cost effectiveness and asked whether there was a practical optimum to the amount of legislation and wondered if such an optimum existed where this might be set in the case of agriculture.

Mr Weeks pointed out that safety was not a question of all cost and no benefit as could be seen by the introduction of tractor safety cabs. Operators are less likely to have accidents in the right environment. Farmers have actually reported that quieter cabs produce more satisfied workers who are less prone to accidents. There is a need to consider the ratio of number of workers to accidents and the seriousness of those accidents. Legislation should be kept in the background and used only where necessary.

Mr Klinner suggested that the distribution of available funds among the various facets of accident prevention should be according to the following priorities.

1 Basic research into accidents and their causes.
2 Investigation into protective and preventive measures.
3 Education of the equipment user, which should be regarded as being of lesser importance and act merely as a bridge.
4 Enforcement which could be regarded as a "last ditch" which although probably necessary cannot be considered as desirable.

I M Abbott (RoSPA) expressed disappointment that speakers had regarded an accident as being synonymous with injury. He suggested that little is known about the accident situation in agriculture — it is only the injury data which is known.

He referred to the RoSPA Survey of Unplanned Incidents which is trying to persuade farmers to appreciate what is actually happening in respect of accidents and near accidents on their farm. One report from this survey indicated that unplanned incidents were costing £3.00/acre on a 1200 acre farm. He suggested that we must study accident situations and not the final outcome — injury. In his experience the people who were having accidents on farms were often experienced and knowledgeable workers — a factor which needed careful investigation.

B C North (Howard Rotavators) was concerned about the frequently occurring phrase in the Act "So far as is reasonably practical". Would it become the responsibility of designers and manufacturers in the case of a court action to convince the court that they had satisfied the condition.

Mr Weeks mentioned that he was unable to speak for the Executive as he was not a member but he felt that the apparent looseness of the phrase is deliberate and that it leaves the designer some discretion in the detail of his product. Statutory requirements could lead to anomalies. For example, in the matter of guards, it has been required only that a component shall be guarded so as to protect the user. The regulation leaves the designer to decide how best to go about this.

Mr Wilder felt that this was a thoroughly commendable attitude to Law and in the best British tradition.

R W Downs (International Harvester of Gt Britain Ltd) reported that he was often asked the question by contractors "Does your machine meet the Health and Safety at Work Act requirements?" He asked was there any thought being given to a form of certification which could indicate compliances with the regulations.

Mr Weeks replied that he was not aware of any such developments.

C V Brutey was concerned that Dr Seabrook had made no mention of the tripartite relationship among animal, machine and man. The physiological responses of livestock to machinery, for example rotary parlours or automatic cluster removers, had not been discussed.

Dr Seabrook emphasised that the study of a cow in isolation is not valid. It must be regarded as part of a man/building/machine/animal complex and in such situations the key factor is man and his relationship with the livestock.

D J Bottoms (NIAE) referred to an Australian survey of 500 tractor accidents. The number of factors contributing to each accident was determined and it was found that on average six factors contributed to each accident. The factors were then classified as relating to:—

1 Surroundings.
2 Behaviour of operator.
3 Design of tractor or machine.

It transpired that of the total of six factors per accident, three were directly related to design. On the matter of dust, Mr Bottoms mentioned a recent legislation covering industrial conditions in Sweden. Agricultural holdings were governed by this legislation where more than five people were employed. Regulations introduced specified that the average organic dust content of the atmosphere experienced by a worker during an eight-hour day should not exceed 10 mg/m^3. He asked if there was any hope of this density being achieved in British agriculture.

Mr Prosser replied that the density specified appears at first sight to be very low and filters to deal with this order of atmospheric dust content would probably require high horse-power fans to effect the necessary air throughput.

J Morris suggested that what we are really trying to do in agriculture is to reduce unplanned farm incidents. However, industries had managed to define a socially acceptable level of risk in respect of accidents and wondered whether agriculture also had a definition.

Mr Weeks reported that this has yet to be done in agriculture and referred to the work of Dr Craig at Sussex University, who in a general survey which gave some consideration to agriculture, he concluded that the tractor cab was one of the better cost effective safety measures in the agricultural industry.

Secretary's Notes

Annual subscription notices 1976

SUBSCRIPTION notices for 1976 were posted to all members of the Institution during the period 9/14 October 1975.

If any member has not received his notice by the time he receives this Journal he is requested to advise the Institution Secretary promptly.

All IAgrE and ERB subscriptions are due on 1 January, 1976.

For those members who use the Bankers Order method of payment, it is hoped that they noted the special instructions enclosed with the renewal notice.

Membership lists

MEMBERSHIP lists covering UK branches or counties and individual countries abroad were distributed to all members of the Institution in July 1975.

It is proposed that amended lists will be distributed in the same manner in June 1976.

If any member is travelling out of his area to any other specific district, the Institution Secretary will be pleased to provide a list of members upon application; 14 days notice would be appreciated.

Certificates of membership Institution of Agricultural Engineers

CERTIFICATES of membership of the Institution are available on application to the Institution Secretary.

IAgrE updating cards

IAGRE updating cards were again sent out with the subscription renewal notice to all members. It would be of considerable help to the Secretariat if members would make use of these cards, as the occasion arises, and send them promptly to the Institution Secretary.

These cards should not be confused with the ERB updating cards, which are used for entirely separate administrative processing.

New appointments

THE Honorary Editor will be pleased to make every effort to publish any information concerning changes of occupation of members in senior appointments.

Details should be addressed to the Institution Secretary.

Journal addresses

THE attention of all members is drawn to the fact that addressed envelopes are prepared for postage to the Journal printers five weeks before the posting date, ie the first day of February, May, August and November.

Journal posting dates are the fifth day of March, June, September and December.

It is regretted that changes of address received after the former dates cannot be incorporated until the following quarter.

County boundaries — England and Wales

ALL English and Welsh members who are resident in an area which has been involved in the change of county names, are reminded that unless they notify the Institution Secretary of their postal code, neither the Institution nor the postal authorities can accept any responsibility for mail not reaching its destination.

Certificates of registration — Engineers' Registration Board

CERTIFICATES of registration for Technician Engineer (CEI) and Technician (CEI) are available at the cost of £3 (including postage and packing) which is payable with order.

Application forms can be obtained from the Institution Secretary.

Due to increases in postage costs it is anticipated that there will be an increase in the cost of these certificates in 1976.

ERB updating cards

MEMBERS who are registered with the Engineers' Registration Board are especially requested to complete the updating card (printed black) as the occasion arises, and send it to the Institution Secretary for annotation and passing on to the Board.

These cards are not to be confused with the IAgrE updating cards which are used for entirely separate administrative processing.

Secretariat end-of-year audit and holidays

THE Secretariat will be closed for all day-to-day business from cease work on Friday, 19 December 1975 until the morning of Monday, 5 January 1976.

This period is intended to cover statutory holidays and audit work.

Honorary representatives

Canada	— L Collins, BSc(Agric) NDA FIAgrE MCSAE 8407–64 Avenue, Edmonton, Alberta, Canada T6E OH1.
Rhodesia	— L Tourle FIAgrE 76 Henley Drive, PO Waterfalls, Salisbury, Rhodesia.
Northern Ireland	— A Lee MAgrSc MIAgrE Taughlane, Hillsborough, Co Down, Northern Ireland.

The Douglas Bomford Trust

THE objects of The Douglas Bomford Trust are to assist in education, training and research in the science and practice of agricultural engineering.

The Trustees are empowered to make monetary grants for scholarships, bursuries, prizes and similar purposes in persuance of these objects.

Applications for awards for the 1976/1977 academic year are required by 1 May 1976.

Applications for special projects can be submitted at any time.

Information regarding awards, and the method of applying for same, may be obtained from The Douglas Bomford Trust, c/o The Institution of Agricultural Engineers, West End Road, Silsoe, Bedford MK45 4DM.

AROUND THE BRANCHES

West Midlands

The West Midlands Branch honorary press officer, Vic Billington, has recently won a scholarship valued at £100 awarded by the Ford of Britain Trust, which will enable him to study aspects of agricultural engineering.

Wrekin

THE IAgrE Wrekin Branch regret to announce the death of L C Hollis earlier this year. "Jim" Hollis had a distinguished career in the electricity supply industry and was the founder chairman of the (then) Wrekin Sub-branch. His friendly manner and firm guidance will be sadly missed by all his Institution colleagues.

Yorkshire

LAST year IAgrE Yorkshire Branch members visited the David Brown Tractors' plant at Meltham, and on 2 October they therefore found it particularly interesting to compare manufacturing and assembly techniques when they were shown round the Wheatley Hall Road, Doncaster, plant of International Harvester. At this plant, IH have a cast iron foundry and they manufacture and assemble complete transmissions for their agricultural tractors. John Maughan, the branch chairman, organised the visit and answered questions following the tour.

ADMISSIONS

The undermentioned have been admitted to the Institution, in the grades stated:—

Member (MIAgrE)

Name	*County/ Country*	*Branch*	*Effective date*	*Occupation*
George J A	S Africa		22 4 75	AD
Lelliott P A	Surrey	13	29 11 74	AD/TS
McCutcheon P	Nigeria		12 6 75	FE

Mani A	Tanzania		16 12 74	
Milne M J	S Humberside	2	29 4 75	FE/RD
O'Dowd M A D	Northants	2	25 3 75	ED
Saw Kok Pee	Malaysia		25 3 75	AD/FE
Stevens N J	Glos	7	1 1 74	ED

Companion (CIAgrE)

Morgan A D	Suffolk	1	10 7 75	CS/DM/RD

Technician Associate (AIAgrE)

Griffiths B H	Yorks	10	22 1 75	TS
Handley R P	Lincs	2	18 11 74	AD/RD
Isaac P	Avon	7	7 5 75	FM
Jones R T D	Herts	5	28 4 75	DM
Newble A L	Kent		22 4 75	AD
Okoye S O	Nigeria		2 8 74	
Oladimeji S O	Nigeria		10 6 75	
Pragnell R E	Norfolk	1	29 4 75	AD/ED
Rigby J S	Worcs	8	22 4 75	FE
Tilbrook R C	Cambs	5	29 11 74	AD/ED

General Associate (AIAgrE)

Ball A F	Salop	9	9 9 75	TS
Cormack A P M	Northumberland	3	22 4 75	FM
Datali G	Malaysia		25 3 75	FE
Deavin R W	Essex	12	29 4 75	FE/TS/FM
Elsey H A	Essex	12	29 4 75	AD/BD
Forbes C P	London		10 6 75	FE
Kirk A R	Northants	2	16 12 74	AD/FE
Lees M A	Yorks	10	14 3 75	TS
Lloyd-Jones R R	Shropshire	9	6 11 73	
McGovern P	Eire		16 6 75	EL
Melville R	Perth	4	21 5 75	TS
Nichols J R	Yorks	10	7 5 75	
Oyekanmi T A	Nigeria		2 8 74	
Pool G S	Hants	13	16 6 75	TS/DM
Pride J W	Lincs	2	22 1 75	AD
Roll R B	Rhodesia		21 5 75	DM/FM
Rooney J C	Oman		21 5 75	FE
Stewart W A	N Ireland		10 6 75	RD
Whitehead R J	Notts	2	29 4 75	TS

Graduate

Binks C	Staffs	9	30 12 74	TS
Bishop C F H	Warks	8	29 4 75	
Choudhary M A	Northumberland	3	25 3 75	RD
Gracey A D	Berks	13	10 6 75	RD
Hong Kee An	Malaysia		16 12 74	CS
King G C	Essex	12	12 3 75	ED
Mahmoud E S	Sudan		5 2 74	
Minihane T F	Kenya		4 10 73	AD/FM
Ross P I	Zambia		1 8 74	
Sims B A	Warks	8	7 11 74	TS
Talabi A E	Nigeria		1 1 74	

Student

Embrey R M	Staffs	9	12 3 75	ED
Ikobho I A D	Beds	5	14 3 75	AD
Jeyakumar S J A	Surrey	13	4 1 74	
Paul G D	Ross	4	4 1 74	
Plom A	Beds	5	22 4 75	FM/RD
Ragunathan A	London		4 1 74	
Stephenson M A	Yorks	10	14 3 75	ED

TRANSFERS

The undermentioned members have been transferred to the grades stated:—

Member (MIAgrE)

Alcock R	Eire		16 6 75	ED
Ashley-Smith J R	Yorks	10	19 4 75	TS
Atkinson J L	Cambs	5	22 4 75	FE
Basford W D	Staffs	9	19 4 75	
Boyce B H	Wilts	7	22 4 75	AD
Cermak-z-Urinova	Aberdeen	4	22 4 75	BD/RD
Chamen W C T	Beds	5	22 4 75	RD
Christie J R	Stirlingshire	4	19 4 75	
Duff J W	N Ireland		22 4 75	
Evans S J P	W Lothian	4	22 4 75	DM
Godfrey G L	Somerset	7	29 4 75	AD/FM
Gordon D J	Australia		29 4 75	FM/RD
Harris P W	Dyfed		28 4 75	FE
Hull P J	St Vincent		22 4 75	ED
Kernahan T	Fife	4	29 4 75	ED
Kitching R B	Lancs	11	29 4 75	
MacPherson W O	Northumberland	3	22 4 75	AD
Major M T W C	Northants	2	22 4 75	BD
Mason G G	Worcs	8	22 4 75	AD/FE
Metianu A A	St Kitts		19 4 75	
Moore A E	W Lothian	4	25 3 75	
Morris D K	Devon	6	21 10 74	
Murison A	Warks	8	21 10 74	ED
Oduyemi I	Nigeria		29 4 75	
Owen J N	Salop	9	22 4 75	ED
Sibley G H M	Warks	8	7 5 75	TS
Vaughan G B	Dumfries	4	29 4 75	ED

Technician Associate (AIAgrE)

Gordon D J	Australia		21 10 74	FM/RD
Hunt G P	Hants	13	19 4 75	

Graduate

Jeyakumar S J A	Surrey	13	9 9 75
Johnson I A	Ayrshire	4	9 9 75
Ragunathan A	Surrey	13	9 9 75

Retired Rate

Annat R B	Warks	8	1 1 75
Baigent H R J	Oxon	13	1 1 75
Cook H W	Kent		1 1 75
Shed G W L	Northumberland	3	1 1 76

RESIGNATIONS

The undermentioned have resigned from membership of the Institution:—

Bates E S	USA		1 1 75
Boa W	Beds	5	17 7 75
Gallagher L V	Yorks	10	17 7 75
Jenkins G W	USA		22 7 75
Kemp I	Herts	5	30 6 75
Payne D M	Essex	12	30 6 75
Poole C R	Notts	2	14 7 75
Proctor R	Lancs	11	30 6 75
Sapsed L F	Essex	12	25 6 75
Shirley I R	Warks	8	20 8 75

DEATHS

We regret to announce the deaths of the undermentioned members:—

Chambers J N	W Indies		18 9 75 (date advised)
Woodland R E	Glos	7	11 3 75

TERMINATIONS

IT is with regret that at the Council meeting on 16 September 1975 it was found necessary to terminate membership of the Institution of the undermentioned persons who have failed to pay their subscriptions.

They are therefore no longer entitled to the privileges of membership, which in the case of corporate members and Associates, includes the use of letters after their name.

Name	*County/ Country*	*Branch*	*Grade*
Aboaba F O	Overseas	—	F
Abu M I B	Overseas	—	TA
Acratopulo J A	Cheshire	11	G
Aiyegbayo D O	Nigeria	—	TA
Allan A M	Lincs	2	G
Andrew T M	Scotland	4	G
Arnold F W	No address	—	G
Khalid Bin Arshad	West Malaysia	—	GA

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Terminations cont

Jefferies T	Cheshire	11	TA
Jefford A W	Australia	–	F
Jeganathan K	London	–	S
Jenkins A	Herts	5	G
Johnson B P	No address	–	GA
Jones B	Yorks	10	GA
Khanna S K	India	–	M
Kellaway D H	Warks	8	M
Kemble-Taylor J	Suffolk	1	GA
Kugaprasad S	London	–	S
Kularatne P K D H	Sri Lanka	–	GA
Lamm A A	Scotland	4	G
Lartey P A	Ghana	–	M
Lawal B A	London	–	GA
Lee C O	West Indies	–	S
Lockwood G	No address	–	G
Lyne J W	Berks	14	M
McKee F A	Westmorland	3	TA
McNaughtan A J	Warks	8	GA
MacNab D	Essex	12	GA
Mahmood R A K	West Pakistan	–	GA
Marengo C E G	W Africa	–	GA
Mensah S S A	Ghana	–	M
Moffat T G	No address	–	G
Mole A C	Bucks	5	M
Morgan J B	Brecon	–	G
Morgan V C L	Worcs	8	TA
Muchiri G	Kenya	–	M
Murray P J	Cambs	5	GA
Mutelo J B	Zambia	–	G
Nelson R J M	Bucks	5	S
Nightingale J S	Dumfries	4	TA
Norman S R	Guyana	–	A
Notley P M	Somerset	6	S
Ofori E T	Ghana	–	S
Ogidi C W	Glasgow	4	TA
Ogundero S O O	Nigeria	–	TA
Ojo A	London	–	S
Okai-Koi N K	W Africa	–	G
Okeji D D	Nigeria	–	GA
Osborne R C	Suffolk	1	TA
Osibanjo Y G	Nigeria	–	S
Ouvry P G D	S Africa	–	S
Owen Smith T	No address	–	GA
Parker W	Leics	2	GA
Parry J G	Gwent	–	M
Patterson T W	Berks	14	GA
Penny R C	Warks	8	M
Pinkerton I M	Essex	12	GA
Plant I	Derby	2	S
Quansah S S	Ghana	–	TA
Quantick H R	London	–	TA
Read T L	No address	–	GA
Robertson M A	Argyll	4	G
Rogers J A	Northants	2	G
Rogerson D L	Canada	–	TA
Ronayne M	Swansea	–	F
Roy S E	Argentina	–	F
Rutherford I	No address	–	S
Sexstone A J	London	–	F
Shah H M	London	–	S
Shaw J C	Canada	–	G
Short R	Hants	14	GA
Sidgwick G N B	Bucks	5	S
Simms R J	Warks	8	M
Singh D P	No address	–	S
Smith G	Derby	2	F
Smith R C	No address	–	GA
Smith W G	Warks	8	M
Snowdon J J	Northumberland	3	G
Soobrian L H P	Guyana	–	G
Spindler J E	Wilts	7	F
Symons M W	Zambia	–	G
Tayal S S	No address	–	G
Taylor N O	Devon	6	GA
Taylor S C	No address	–	S
Thacker G	No address	–	GA
Thakrar H G	E Africa	–	TA
Twissell N B	Glos	7	G

Turner T	Warks	8	TA
Uma I	Kampala	–	G
Vinter J	Lincoln	2	M
Wardle A P S	No address	–	TA
Bailey A H	Cambs	5	G
Balendran S K	London	–	S
Bari S	No address	–	M
Barnes W S	Essex	12	G
Bates B G	Essex	12	GA
Bateson K G	No address	–	G
Bertrand A T	No address	–	GA
Bindloss K W E	No address	–	GA
Birchall-Kent E L	Sussex	14	GA
Boden C E	Lincs	2	TA
Boothroyd H	No address	–	M
Bowman A M	Dumfries	4	G
Brix P	Dorset	7	G
Brockett R G	Cambs	5	GA
Bryant S	Devon	6	G
Butcher M	Kent	–	GA
Castling D R	Rhodesia	–	GA
Causer D A	Stafford	9	GA
Charlesworth M C	W Australia	–	G
Clark R	Preston	11	GA
Coffey D M G	Eire	–	M
Cole P L	Warks	8	TA
Coleman F T	No address	–	GA
Coles E D	S Africa	–	F
Comber H L	Yorks	10	M
Cooley A R	Oxon	14	S
Cousins S B A	No address	–	G
Crowe W I C	Oxon	14	GA
Crowter D	Warks	8	GA
Cutting R N	Berks	14	G
Davies G S	No address	–	G
Davis T J	Renfrewshire	4	S
Day M J	Beds	5	TA
Delgoda R S	London	–	G
Dent A A	West Lothian	4	G
Disney R E L	No address	–	G
Dodd R R	No address	–	GA
Duncan R D	Canada	–	TA
Dyson C R	No address	–	M
Edmunds M J	Devon	6	TA
Ellison J F	No address	–	M
Endale D	Ethiopia	–	S
Etherington C H	No address	–	G
Fletcher D	Worcs	8	GA
Ford J E	London	–	S
Forrester R	Canada	–	GA
Foskett K D	No address	–	S
Franke R	No address	–	F
Fraser J M	London	–	G
Frost J W F	Hants	14	TA
Galindez F	Berks	14	S
Gee-Pemberton H W	Cheshire	11	M
Gibson R J F	No address	–	S
Gollop W	No address	–	S
Goodger C A	Oxon	14	C
Goodwin A C	Suffolk	1	M
Gundry R G	Glos	7	TA
Hanavan M T	W Australia	–	M
Hancock P N	Northants	2	G
Hansom G S	Yorks	10	GA
Harris C H	Glasgow	4	GA
Harvey J L	London	–	GA
Hayward A R	Canada	–	G
Heer J P de	W Africa	–	M
Herath K	Sri Lanka	–	M
Hickey P K	Dublin	–	M
Hill R J A	Zambia	–	G
Hodges L S	No address	–	F
Horner C G	Saudi Arabia	–	GA
Howland J L	Staffs	9	M
Hussein M H M	Sri Lanka	–	TA
Iles G A	No address	–	F
Imran S A	Pakistan	–	M
Irwin Q F	Tokyo	–	GA
Irugbokwe I S	Nigeria	–	M

Wardrop G	Kent	–	F
Warren J D	Dorset	7	TA
Warrilow E L	Staffs	9	GA
Webb A E	Suffolk	1	M
Webb H R	Australia	–	M
Weston P E	Cambs	5	TA
Wharton F N	Co Down	–	GA
Wijewardene R	Nigeria	–	M
Wilkinson M A	Notts	2	G
Williams G A	Gwent	–	S
Williams R	Northumberland	3	TA
Williamson D A	No address	–	G
Wilson E J G	Pembroke	–	GA
Woodward R E	Shropshire	9	G
Wosu A R	Nigeria	–	M

ENGINEERS REGISTRATION BOARD

The undermentioned have been placed on the ERB (CEI) Register:—

Technician Engineers (TEng [CEI])

Alcock R	Co Kerry		10 9 75
Anazodo U G N	Nigeria		10 9 75
Ashley-Smith J R	Yorks	10	5 6 75
Atkinson J L	Cambs	5	5 6 75
Barton J M	Leics	2	10 9 75
Bell D A	Cumbria	3	5 6 75
Boys P D	Canada		5 6 75
Butcher F J	Kenya		5 6 75
Castle D A	Lincs	2	5 6 75
Christie J R	Stirlingshire	4	5 6 75
Duff J W	Co Tyrone		10 9 75
Duggleby T J	Norfolk	1	10 9 75
Evans S J P	W Lothian	4	10 9 75
Finn-Kelcey J P	Oman		5 6 75
Hull P J	St Vincent		13 6 75
Jessup R W	Warks	8	5 6 75
Jones K G	Bristol	7	10 9 75
Kernahan T	Fife	4	13 6 75
Lyford-Smith A	Worcs	8	5 6 75
McKinlay W W	Swaziland		5 6 75
Matthews M D F	Beds	5	5 6 75
Milne M J	S Humberside	2	10 9 75
Morris D K	Devon	6	10 9 75
Nketiah A K	Ghana		5 6 75
Nwankwo J O	Nigeria		10 9 75
Owen J N	Salop	9	13 6 75
Pascal J A	Peebles	4	10 9 75
Platt G D	Lincs	2	20 1 75
Rees M E	Dyfed		5 6 75
Robinson J R	Beds	5	10 9 75
Sparkes F A J	Staffs	9	13 6 75
Stirling H G	London		10 9 75
Tofts J N	Norfolk	1	10 9 75
Vaughan G B	Dumfries	4	13 6 75
Wall B P	Turkey		10 9 75
Willy R J	Berks	13	5 6 75

Technicians (Tech [CEI])

Bhatti I A	Nigeria		10 9 75
Campbell C S	Notts	2	10 9 75
Cherry R P	Greece		10 9 75
Daubney N J S	Yorks	10	10 9 75
Fountain C G	Essex	12	5 6 75
Gordon D J	Australia		5 6 75
Griffiths B H	Yorks	10	5 6 75
Hannah J R	Bristol	7	10 9 75
Hibberd K I	Wilts	7	13 6 75
Hunt G P	Hants	13	5 6 75
Jobling J E	Yorks	10	10 9 75
Jones R T D	Herts	5	5 6 75
Newble A L	Kent		5 6 75
Oladimeji S O	Nigeria		10 9 75
Pragnell R E	Norfolk	1	13 6 75
Swift J R R	Rhodesia		5 6 75
Tilbrook R C	Cambs	5	13 6 75
Voss R M	Warks	8	10 9 75
Watson P D	Tanzania		5 6 75
Wise P M	Lincs	2	5 6 75

Situations Vacant