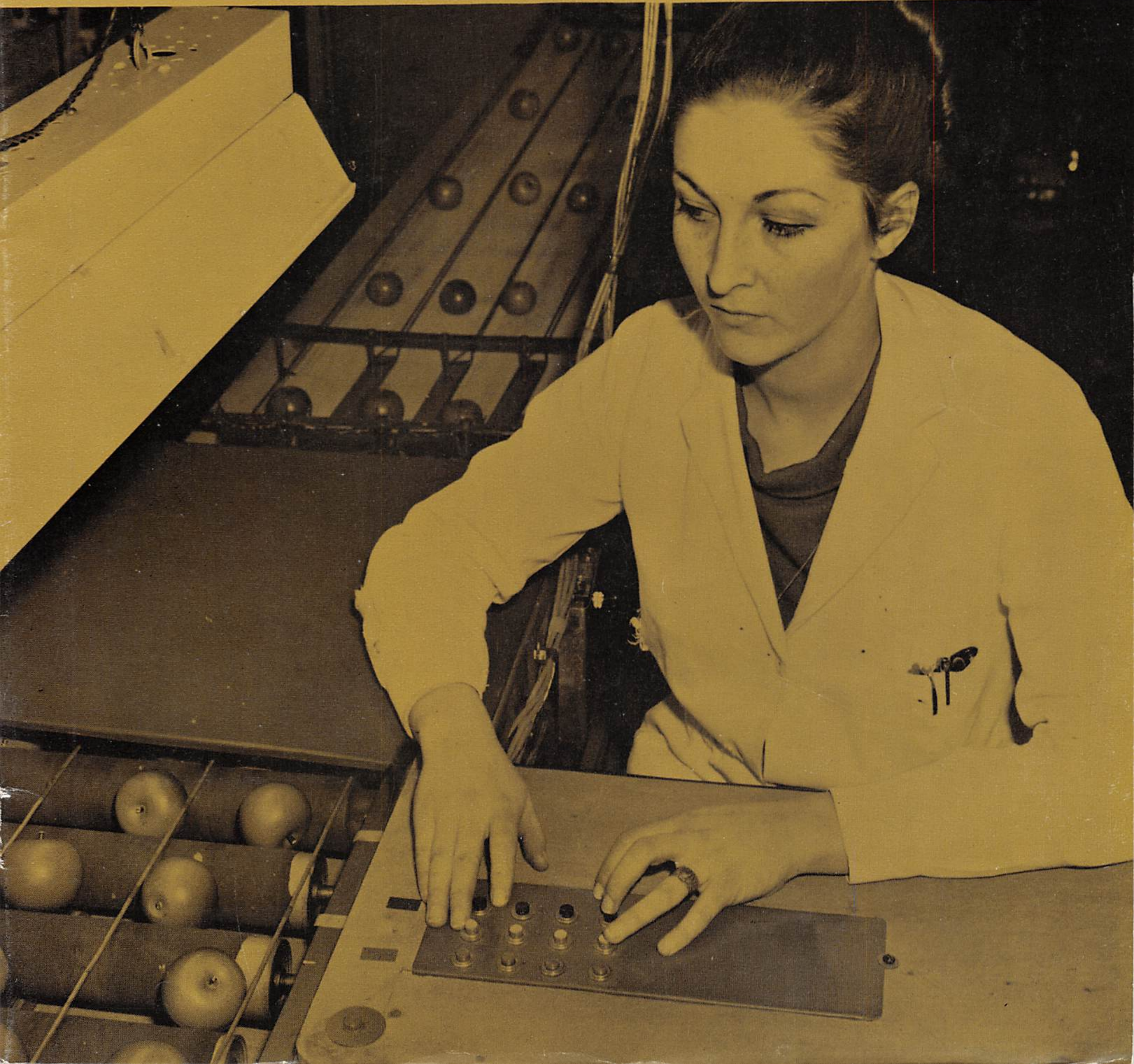
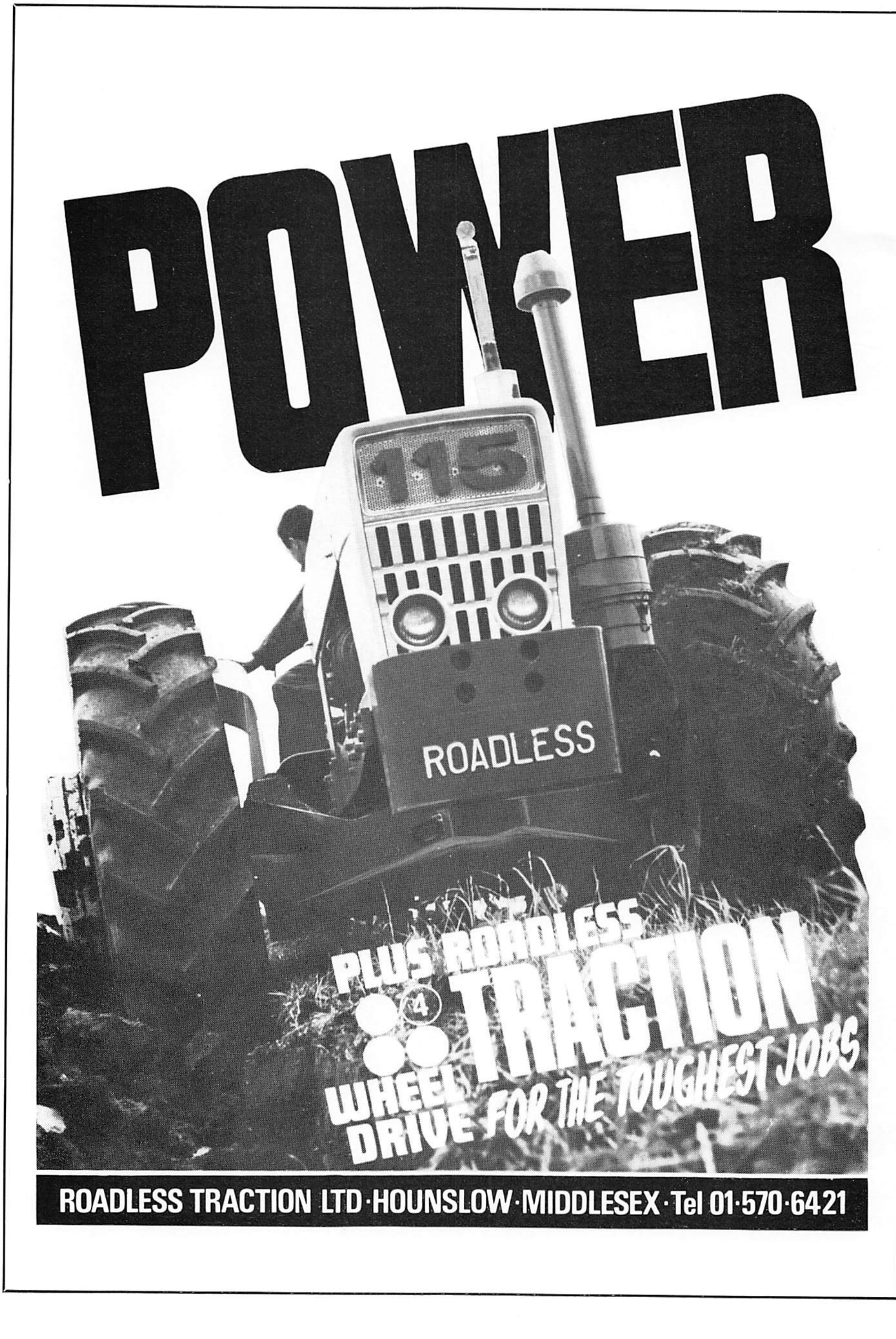
I AGR E

Volume 25
Number 1
Spring, 1970

ERGONOMICS IN AGRICULTURE

Work Load in Agricultural Tasks
Combine Harvester Operation
Development of Operational Skills
Quality Inspection of Horticultural Produce

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THE INSTITUTION of AGRICULTURAL ENGINEERS

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The Front Cover illustration is from Figure 7 of the paper by G. N. Stevens

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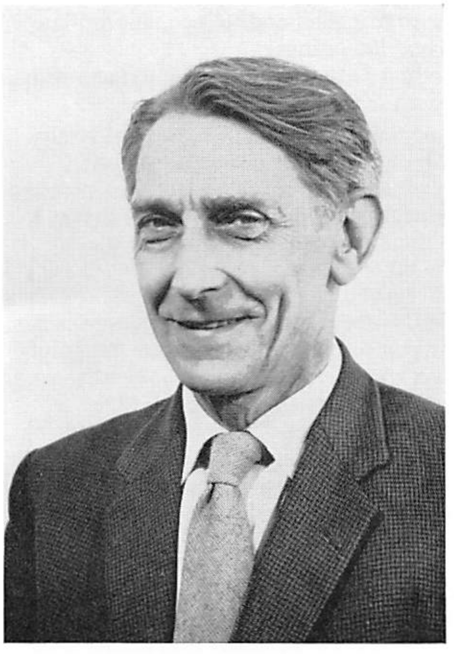


With much of this issue of I AGR E being devoted to the subject of ergonomics, it was thought appropriate to invite Professor W. F. Floyd, a leading authority in this branch of science, to make this individual contribution.

Professor Floyd has been Head of the Department of Ergonomics and Cybernetics at Loughborough University of Technology since 1960. The Department was set up initially as a research Department to undertake research studies in human factor problems, particularly in regard to industry. The Department now offers two undergraduate courses leading to degrees in Ergonomics and Human Biology, and three postgraduate courses, two in Ergonomics and one in Human Biology.

The Department undertakes a substantial amount of research work under contract for industry and for various government departments. It is currently engaged in studies of the effects of vibratory and impulsive forces on man; in dynamic anthropometry in relation to work space layout, posture and movement in work situations; in ergonomics problems of operating agricultural machines; in studies concerned with vision and lighting; in studies of the work load imposed by various tasks including piloting aircraft and parcel sorting. In addition the Department is rapidly expanding its studies in the field of consumer ergonomics including the ergonomics of disablement, and is also conducting studies related to the ergonomics of the food industry.

Professor Floyd is a member of various committees concerned with human factor problems, including the Road Safety Research Committee of the Ministry of Transport Road Research Laboratory, and the Agricultural Research Council's Standing Committee on Agricultural Engineering Research. Professor Floyd is also chairman of the Advisory Committee on Ergonomics and Anthropometry of the British Standards Institution.
Professor Floyd is interested in farming, particularly livestock rearing. He breeds pedigree Welsh Black cattle and Welsh Mountain sheep and ponies.

ERGONOMICS IN AGRICULTURE

by PROFESSOR W. F. FLOYD

What is ergonomics?

Ergonomics can be described as the science of human performance. It deals with the capabilities and limitations of human endeavour at all kinds of work tasks carried out in all manner of environments. In his studies of the man/machine problem the ergonomist uses knowledge about human behaviour derived from the human biological sciences, and especially anatomy, physiology and psychology, linked with engineering technology. This gives an approach to machine design through conventional engineering and technology aided by the application of human biology. It takes account of the shape and size of the body and of factors concerned with movement, posture, hearing and seeing, with due regard to accuracy, speed and safety of operation.

When applied to the study of human activities, ergonomics leads to the increase of human efficiency at work and to the improvement of well-being through better design of equipment and more adequate control of environment. The ideal machine designed through team work by engineer, designer and ergonomist, can properly be described as "fit for human use". It will be matched to operators so that they use their abilities to the best advantage consistent with such performance criteria as safety, fatigue, stress, speed and accuracy.

Ergonomics has been successfully applied to many industrial and military problems including, for example, the design of control cabins for cranes and rolling mills and for the detailed design of the many components used in the control situation, such as the meters and other instruments which display information, and the knobs, control levers and keyboards by which the operator carries out his control function. Ergonomics has also been applied to the design of buildings for a multitude of purposes and to the design of furniture and equipment of all sorts used in schools, offices, hospitals and factories, as well as in the home.

Can ergonomics help agriculture?

There is a large and important part for ergonomics to play in agriculture through the improvement of conditions of work and through the design of agricultural machinery. A modest acquaintance with agricultural machines shows them to have been ruggedly and solidly built, intended for heavy duty and built to last a very long time. Machinery of newer design has more recently shown a breakaway from this older tradition, and recent advertisements in farming journals wish us to believe that the new equipment is designed with the needs of the farmer foremost in mind. What are the facts about ergonomics in application to agricultural machinery and equipment?

It might be thought that a major area of application could be in regard to problems of heavy work, whether manual or with machines, since heavy work has always seemed inseparable from the agricultural task. It is true that much manual work will continue for a long time, especially on smaller farms, because of the considerable existing investment in unsuitable buildings and equipment and because of the high cost of replacement machinery. This is an interesting and important area to develop but is neither the most important area of application of ergonomics in agriculture, nor is it the area of particular interest to agricultural engineering.

There is a diminishing labour force in agriculture and a continued need for increased productivity, which means intensification of stocking and cropping. In order to make farming pay, agricultural machinery must be economically viable for the enterprises within which it is to be used. This means that the human factor in the operation and control of the machine must be used at the optimum in all the various operations involved.

There has been growing recognition of the importance of human factor problems in agricultural machinery design during the past few years but insufficient work has yet been done in applying ergonomics in the design of new machinery and equipment. There is an increasing number of papers reporting studies of particular areas which are a direct carry over from industrial and military applications of ergonomics, such as in tractor seating, control layout and posture, but there has been very little attention paid to the systems approach.

A lot of attention has been paid to ride comfort of agricultural tractors, but planters, trailed behind tractors, still are among the worst offenders in regard to posture and vibration. In the cowshed radical improvements in design have greatly reduced the physical load of the daily work routine, but the flow-rate of information, like that of milk, has increased enormously, with the result that the cowman is almost certainly under substantial stress keeping pace with the demands of modern milking equipment and the milking parlour.

Agricultural machinery is noisy and exposure to noise levels found that some of these machines lead to temporary deafness. Such deafness can last for many hours and, if exposure is continued long enough, the result may well be permanent loss of hearing. The removal of this noise hazard from the agricultural scene will almost certainly be accompanied by improvements in performance since noise is well known to interfere with efficient performance of work tasks.

The designers of agricultural machinery have made little attempt to supply the operator with adequate information about the operating state of the machine. This again leads to inefficiency of operation, and much more consideration should be given by designers to the flow of information across the interface between operator and machine. Successful row-crop cultivation is dependent upon adequate feedback of information from the work so that the operator can carry out the control function. Often, the essential parts of the machinery involved in the operation are not visible to the operator, or only some part can be seen from any one driving position. Inefficiency is bound to result when this obtains.

The systems approach can only be used effectively when consideration is being given to radical and extensive re-design. The essential features of this approach are:
- to assess and specify the needs of the system;
- to allot functions to machines and to men, appropriate to their abilities and limitations;
- to design the machines to match at their interfaces with their machines and the men in the system.

When the systems analysis and design has been correctly carried out, the task of the man is not only matched physically and perceptually to a machine, but the operating range falls within the proper limits of reasonable demand, avoiding the stress due to excessive demand and the boredom due to the other extreme.

It is at this point in the design process that ergonomics has the most important part to play, influencing the design of controls and displays employed at the interface and the quality or nature of the information flow across the interface. For example, the level of accuracy called for by the system must fall within the range that could be achieved by the man using the type and quality of information flow and the nature of display proposed for the equipment.

There is very little sign as yet that agricultural engineers are getting to close grips with these problems. It is not that the agricultural engineering is deficient in any engineering sense, but there is a failure to acknowledge the importance of the ergonomic approach. When under pressure to cut his costs, the agricultural engineer is still willing to ignore the human factor or to assume that the man can operate his machine if it is good enough engineering-wise. The more fruitful approach would be to retain the human factor study and to cut back on some of the engineering, thereby ensuring that such engineering as it is possible to provide within a limited budget of research is none the less effective operator-wise. □

INSTITUTION NOTES

The Institution and CEI

According to the Institution's President, Mr H. C. George Henniker-Wright, the situation of agricultural engineering in relation to the Council of Engineering Institutions (CEI) gives rise to 'more rumour, speculation, gossip, disquiet and general misunderstanding than anything else in sight at the present time'. So he has been saying during his spring visits to some of our Branches and it is easy to see why.

The problem is a complex one. Since 1965, the only way of becoming registered as a Chartered Engineer (C Eng) has been (and still is) to become a corporate member of one of the chartered institutions who are constituent members of CEI. There are only fourteen such institutions and I Agr E is not one of them. Even if it wanted to, it could not become a constituent member because the Institution does not yet have a charter of its own; this is still a primary requirement.

The rules governing entry to Fellowship of our Institution are already well up to the standard that CEI will be requiring its constituent member institutions to put into effect by 1974. But if our Fellows want to register as Chartered Engineers they must at present join one of the fourteen chartered institutions which most nearly accords with their own career background.

Let's be fair. There is a good deal of sympathy in CEI circles for some of the very reputable non-chartered institutions, including I Agr E, who are placed in this awkward dilemma. And there is a growing willingness to bring the problem into the open and discuss possible solutions. It all takes time.

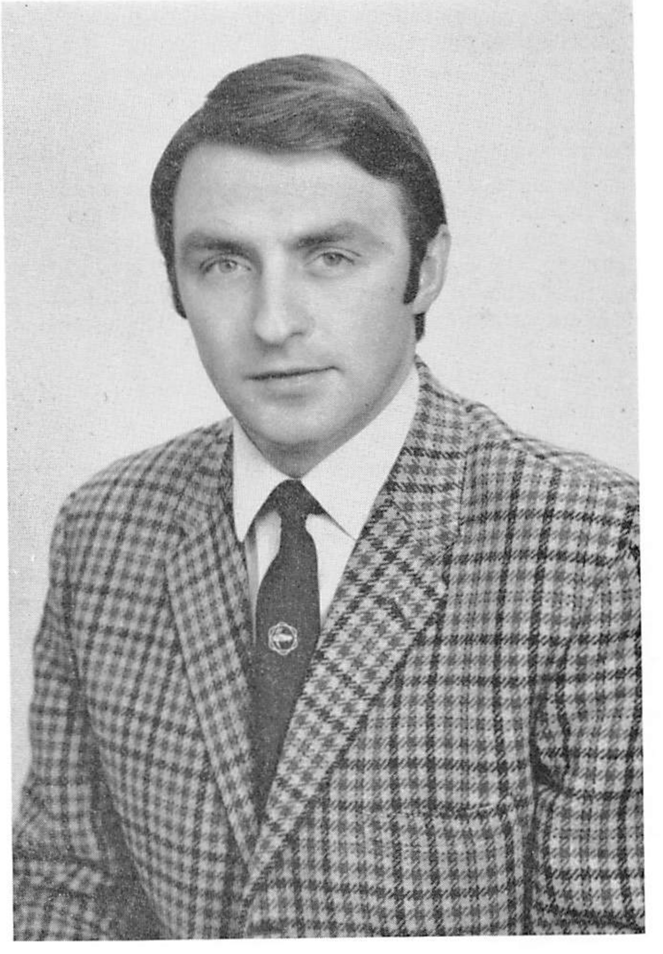
On the other hand, things are moving fast and in a very exciting way with regard to the diploma-level technician engineer. CEI can set out with a clean slate to tackle the subject of a national qualification and title for this important section of the engineering community. It shows every intention of setting up a composite register with the minimum delay, as readers of our Newsdesk feature in recent issues of the *Journal* will have discovered. The Institution is closely linked with this development.

The importance of this to hundreds of agricultural engineers qualified at the ND Agr E level of attainment and ability cannot be too strongly stressed. It is all described in the Presidential Message recently circulated to all I Agr E members, and which appears also on pages 10 and 11 of this issue.

The President, in his message, places great emphasis on the desirability of I Agr E becoming affiliated to CEI. He believes this would secure the status of agricultural engineering as a recognised sector of British twentieth century technology, under the mandate of the CEI Royal Charter. This, plus the facility for registering diploma-level agricultural engineers via I Agr E through the medium of the CEI Charter, could be an immense stride for the agricultural engineering community and mean a greatly enhanced reputation for the Institution.

Annual General Meeting

This is a more than usually important AGM. It is a mile-stone event, at which members are to be asked to pass a Special Resolution empowering the Council to negotiate the Institution's affiliation to CEI.



Mr. Keith Charles Ward, a former student of West of Scotland Agricultural College, wins the 1969 Johnson Medal (see "Scottish Hat Trick" overleaf).

Every member who can come to the AGM ought to be there. It will be held in the Lecture Hall of I Mech E, 1 Birdcage Walk, London SW1, on Tuesday, 12 May 1970 at 10.00 hours.

Annual Conference and Dinner

As an added, if cunning, incentive to come to London on 12 May, the Institution will hold its Annual Conference on the same day, at the same place, and immediately following, the AGM and Presidential Address.

A highly workman-like programme on 'Cultivations' has been put together by the convenor, Norman Brown of Rothamsted Experimental Station. Full details and ticket order forms were circulated to members recently; more are available on request, and details are also given on the inside back cover of this *Journal*.

To round off the day in agreeable style, the Annual Dinner of the Institution will be held at nearby St Ermin's Hotel. The Guest Speaker will be Mr J. W. Beith, Managing Director, Massey-Ferguson (United Kingdom) Limited, and who should, if matters follow their planned course, be President of the Agricultural Engineers Association Limited by 12 May.

The Conference and Dinner are open to members and non-members alike. As in show business, its the audience that counts. And taking all things together, 12 May looks like being a big day.

Scottish Hat Trick

The Johnson Medal is awarded to the most successful student in the examinations for the National Diploma in Agricultural Engineering. And the competition gets keener, with the swelling number of candidates from one year to the next. In 1969, there was a record total of 91 entries, spread over the centres in England and Scotland.

Congratulations, then, to Keith Ward who secured distinctions in all subjects and earned himself the Institution's Johnson Medal for a performance of exceptionally outstanding merit. Mr Ward started out with a couple of years of farming and then studied at Kesteven Agricultural College. There he gained the City and Guilds certificates which helped him get a place on the ND Agr E course at West of Scotland Agricultural College. He now works for the National Agricultural Advisory Service. When he gets the chance, he enjoys a spot of motor rallying and a game of rugger.

It's a hat trick for Scotland. Congratulations to West of Scotland Agricultural College on producing three Johnson Medallists in three successive years.

Putting it Prettily

As promised, the *Journal* comes clad in new apparel for the 1970's. The aim is to combine an undiluted standard of technical excellence with a more free-wheeling visual appeal. In short, the *Journal*—doubtless like the lady on the front cover (and whose identity, please note, the publishers will *not* disclose to students of agricultural engineering)—aims to be more than just a pretty face. □

FORTHCOMING EVENTS

LECO '70

4-7 May 1970
Royal Festival Hall, London

The London Engineering Congress organised by The Council of Engineering Institutions
Enquiries to the Congress Office,
10 Chesterfield Street, London WX1 8DE

CEI GRAHAM CLARK LECTURE

6 May 1970 at 18.30
The Institution of Electrical Engineers, Savoy Place, London WC2

16th Graham Clark Lecture entitled "This Engineering Age" by Sir Henry Jones, KBE, Chairman of the Gas Council
The lecture is included in the LECO '70 Congress programme

IRRIGATION AND SLURRY DISPOSAL DEMONSTRATION

7 May 1970
Norfolk School of Agriculture, Easton, Norfolk

A full scale farm demonstration organised by the Norfolk Farm Machinery Club
Enquiries to J. B. Mott, MI Agr E,
County Organiser, Norfolk Farm Machinery Club,
County Hall, Norwich NOR 49A

CULTIVATIONS

12 May 1970 at 11.00
Institution of Mechanical Engineers,
1 Birdcage Walk, London SW1

The Annual Conference of the Institution of Agricultural Engineers. For full details and enquiry procedure, turn to inside back cover.

ELMIA '70

4-9 June 1970
Jonkoping, Sweden

A main theme of this, the 10th ELMIA trade fair, will be transport on and off the farm
Enquiries to Exhibition Consultants Ltd,
11 Manchester Square, London W1

ROYAL SHOW

7-10 July 1970
National Agricultural Centre, Kenilworth, Warwicks

The largest agricultural machinery and livestock exhibition in Europe
Enquiries to Royal Agricultural Society of England,
35 Belgrave Square, London SW1, or to
the National Agricultural Centre

18TH INTERNATIONAL COURSE ON RURAL EXTENSION

1-25 July 1970
Wageningen, Netherlands

Organised by the International Agricultural Centre under the patronage of FAO and OECD, the course aims to pool ideas on extension methods and promote international understanding of the problems
Enquiries to The Director, International Agricultural Centre, P.O. Box 88, Wageningen, Netherlands

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9TH INTERNATIONAL COURSE ON LAND DRAINAGE

31 August-11 December 1970
Wageningen, Netherlands

Organised by the International Institute for Land Reclamation and Development and the International Agricultural Centre. The course is in English.
It is at post-graduate level and participants should have a university degree in irrigation and drainage agronomy, irrigation or drainage engineering
Enquiries to The Director, International Agricultural Centre, P.O. Box 88, Wageningen, Netherlands □

NEWSDESK

1970—European Conservation Year

In the seven years since 1963, when HRH Prince Philip inaugurated the first conference on 'The Countryside in 1970', awareness of the conflicting claims on the shrinking areas of rural land surrounding our rapidly-growing towns has become widespread. 1970 is not only to provide the occasion, in November, for the third British 'Countryside in 1970' Conference, but has also been designated 'European Conservation Year'.

The aims of the twenty or more countries working together in European Conservation Year are two-fold—to establish policies on and methods of conserving and improving the quality of the environment in which we live, work and find our recreation, and to draw attention to conservation problems so that the public will understand the need to deal with these problems, and, it is hoped, be prepared to support necessary measures.

Conservation in its modern sense does not mean 'preservation' of the countryside in a fossilized state of development. Instead, its aim is to take a broad view of the nation's land area as a national asset, so that conflicting claims can be evaluated and resolved, despoliation avoided and adverse pressures controlled. Planning authorities can then be encouraged to develop constructive methods of planning in which the quality of the environment as a whole is considered, rather than merely the solution of short-term problems.

Agricultural engineers are involved in conservation in two ways. First of all, most agricultural engineers live in the countryside and are likely to be among those immediately affected by the pressures European Conservation Year seeks to define and develop means to control. Secondly, agricultural engineers are concerned with the design and to some extent the use, of machines and equipment used in farming, which may have a direct effect in improving or detracting from the quality of the environment. Such quality includes visual amenity and the presence or absence of noise and smell, while other factors may include aspects of water and air pollution, chemical application and waste disposal, as well as positive measures for improving derelict and other land.

The Institution of Agricultural Engineers has been represented in the pre-conference committee work of both the 1965 and 1970 'Countryside in 1970' Conferences, in the Study Group on Technology and the Countryside and the Professional and Technical Services Liaison Committee respectively. In the pre-conference discussions and at the 1965 Conference it was clear that the number of non-agricultural interests and of those who use the countryside simply for recreation, vastly outnumber those whose living and work is in farming and agricultural engineering. The imbalance is confirmed by the statistics which now show that in England and Wales only 2·9% of the population is actively engaged in agriculture. For Great Britain as a whole the figure is under 4%.

The hundreds of non-agricultural interests range from the vast nationalized corporations concerned with gas, coal and electricity to associations of anglers, cyclists, campers and dozens of others. In between these and the agricultural population there are to be found the land-linked professions, such as surveyors, landscape architects, town-planners, civil engineers and agricultural engineers. In the report of the Liaison Committee mentioned, to be presented at the Countryside in 1970 Conference in November 1970, the recommendations will emphasize the need for these professions to work together in the interests both of their clients and of the needs of conservation as a whole.

During the next 30 years the projected increase in the population in Britain is from 55 million to 70 million, while by the year 2000 it is anticipated that there will be 28 million cars on British roads, compared with 10 million today. The agricultural population will be much smaller than now proportionately and in absolute numbers, while the area of rural countryside will be reduced. However pressing the problems of conservation are today, it is absolutely clear that they must become much greater, accelerating in difficulty as time goes by. Agricultural engineers will have new opportunities to serve the farming community by helping to solve problems of pollution, in catering for the intensified systems of farming that the declining land area will necessitate and no doubt in many other ways. They will also have new opportunities as the engineering body particularly dedicated to the needs of the countryside, for working with professional men of other disciplines in serving the wider aspects of conservation.

Further information on European Conservation Year can be obtained from: The ECY Secretariat, 19 Belgrave Square, London SW1.

British Engineers May Register in Europe

Engineers in Britain may soon be able to apply for their names to be listed on a European Register of 'higher technical professions', following an agreement with the Federation of European Engineering Institutions. This would enable industrial companies and other employing bodies in Europe to establish the qualification of British engineers, and it could be expected to improve the chances for international exchange of such engineers.

The development is in line with the wishes of the European Parliament—one of the Common Market institutions—to see a free exchange of technical and other skilled personnel between the EEC and other countries, in support of projects involving joint collaboration.

A European Register of practising engineers is to be established, according to a recent edition of *Electrical Review.* This will be divided into two main professional groups and it is understood that Federation representatives have agreed that the qualifications laid down by the Council of Engineering Institutions in the United Kingdom would enable British chartered engineers to be accepted for the higher grade on the Register.

Chartered engineers will have to apply for registration via the British National Committee of the Federation and will be issued with a type of European 'engineer's passport'.

It is also hoped that in time British technician engineers will be able to apply for registration on another section of the Register. This would be in line with CEI proposals (described in previous editions of *Newsdesk*) for the establishment of a single British registration authority for chartered engineers, technician engineers and technicians.

Centre for Agricultural and Food Production Structures

A new emphasis has been given to research and teaching on buildings for agricultural production and food processing by the establishment within the University of Reading of a Centre for the Study of Agricultural and Food Production Structures.

The Centre, which will implement a recommendation made in 1964 by the Bosanquet Committee, will bring together relevant work in several Departments of the University, such as Agriculture, Estate Management, and Building and Quantity Surveying. It will seek to develop further research in collaboration with a range of other Departments, including particularly Agricultural Economics, Applied Physical Sciences, Civil Engineering, Food Technology and Horticulture. Existing teaching work, including the MSc course in Agricultural Building and parts of BSc courses in Agriculture, Horticulture and Estate Management will continue in the various Departments as previously. It is hoped that new courses will be introduced as the Centre develops.

Research already in progress in the University includes studies on environmental control for pigs and poultry, economic aspects of farm building use, design and layout of farm buildings, etc. It is intended that the Centre will also initiate studies on equipment and buildings for the processing of agricultural products which forms the first link outside the farm gate in the chain between primary producer and retail purchaser. In developing this new field as well as providing a focus for the University's existing interests in agricultural building, livestock production, crop storage and food technology, the work of the Centre will complement other work already in hand at the Farm Buildings Centre, the National Institute of Agricultural Engineering and the Colleges of Agriculture in the North and West of Scotland.

The centre is established within the Faculty of Urban and Regional Studies and located initially with the Department of Agriculture. The acting Director is Mr J. A. C. Gibb, who is Senior Lecturer in Agricultural Engineering at the University of Reading, Earley Gate, Reading RG6 2AT. He is also a leading figure in The Institution of Agricultural Engineers, of which he is currently a Vice-President, as well as being Chairman of the Examination Board in Agricultural Engineering.

New Qualifications for Talented and Outstanding Agriculturalists

The Royal Agricultural Society of England, The Royal Highland and Agricultural Society of Scotland and The Royal Welsh Agricultural Society have instituted jointly a distinctive senior award in agriculture. This takes the form of an Associateship leading to Fellowship of Royal Agricultural Societies, to be distinguished shortly by the letters ARAgS and FRAgS respectively.

The purpose of the award is the creation of a high calibre qualification, linking practice with science, for talented and outstanding agriculturalists (men or women) who, though they may already have a recognised qualification, wish to have a professional seal set on their achievement. As well as enhancing the prestige of the holders, the award must prove to be of continuing value in the industry during the most active part of their working lives. The scheme is designed for those whose work comes within the technological, managerial, business and commercial and administrative fields of agriculture interpreted in the widest sense to include the ancillary industries, also for those in the advisory and educational services. Associateship (ARAgS) will be awarded for a treatise or dissertation on an approved subject, after a suitable period of study, which reveals a depth of knowledge and evidence of an understanding of the broader field of agriculture. The procedure will be for a candidate after leaving college or university to engage himself on an approved project for a minimum of one year in a particular field of agriculture. Approval to commence a project will not normally be given until the candidate has gained two years' experience in the industry after having left his teaching institution.

Fellowship may be conferred not less than ten years after qualification for the first award, on evidence of the attainment of a high level of both service to and achievement within the agricultural industry. It is reserved for those who are making a mark in the profession and will not normally be awarded before a person has reached 35 years of age.

A Fellowship body is being appointed initially of eminent people in the agricultural field. The three Royal Agricultural Societies concerned have instituted a Council of Fellows to be responsible for the selection of candidates for Associateship and Fellowship and conferment of awards. Except insofar as Fellowship may be conferred at the discretion of the Council of Fellows during the initial ten year period, progression to Fellowship will normally be through Associateship. While the initial appointment of Fellows is being made by the parent Societies, in whom is vested ultimate authority, the Council of Fellows will have wide freedom of action in making awards of Associateship and Fellowship.

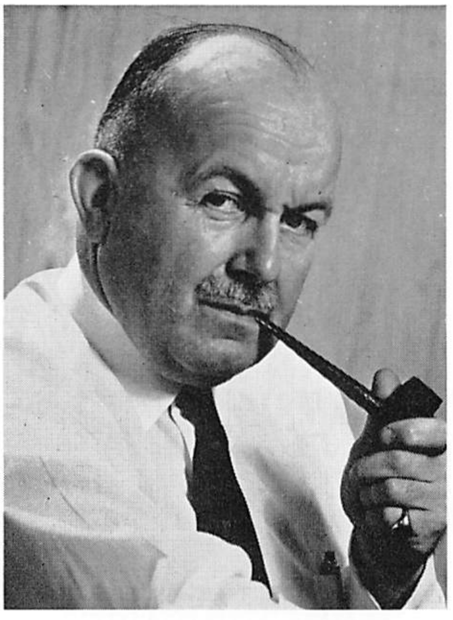
The scheme was launched on 1 April 1970 and copies of the Conditions of Award and of the Form of Application for admission to the Associateship scheme may be obtained from the Secretary, Council of Fellows of Royal Agricultural Societies, 35 Belgrave Square, London SW1. □

AUTOMATION IN FARMING

This will be the main theme in the next issue of the "Journal". There will be full coverage of the Conference held in London on 25 February, 1970 under the joint auspices of the Electricity Council and The Institution of Agricultural Engineers. Watch out for this and all our regular features in:

I AGR E/SUMMER 1970/VOLUME 25/NUMBER 2.

A message from the President of the Institution of Agricultural Engineers to all members.



THE INSTITUTION AND CEI

by H. C. GEORGE HENNIKER-WRIGHT, MEM ASAE, FI AGR E

Dear Member,

The Council of Engineering Institutions (CEI) announced recently that it proposes the establishment of a composite register to cover the main sections of the engineering community— currently, chartered engineers, technician engineers and engineering technicians. The Institution of Agricultural Engineers has long been engaged in consultations with CEI, I Mech E and SCNQT (the latter being The Standing Conference concerned with helping to establish national qualifications and titles for technician engineers and engineering technicians).

The I Agr E Council has repeatedly pledged that the status of the agricultural engineer at all levels, ranging from degree to diploma standards of attainment and ability, must be safe-guarded. We believe this can best be achieved by your Institution becoming formally affiliated to CEI. A resolution to this effect is to be laid before you at our Annual General Meeting in London on 12 May 1970. I want you to be fully informed as to what this is all about and why I hope you will feel able to approve the resolution.

Your Council has for many years been convinced of the need to be associated with CEI so that agricultural engineering can acquire its proper status and play its full role in human society. Many engineers already benefit from the privileged status which stems from belonging to one of the current constituent member institutions of CEI.

This naturally leads one to ask the question, 'Why then has I Agr E not applied for constituent membership of CEI? The blunt truth is that we cannot even begin to think of applying for constituent membership until the Institution is granted its own Royal Charter. This remains one of our aspirations, but at the present stage of our development, there is no prospect of a Charter being attained in time to be of practical value to the situation that confronts us today. In any case, your Council has grave doubts as to whether constituent membership, even if it were readily attainable, is the right answer for the agricultural engineering community. In the first place it would mean that admission to corporate membership, whether as Fellows or Members, would thereafter be closed to all except degree-level agricultural engineers. It would mean that future diploma-level engineers—the ND Agr E holder and his like—would henceforth not be able to gain admission other than as Associates. This latter grade, being non-corporate, was never designed as a career yardstick for the qualified and experienced agricultural engineer. The Council cannot believe that our young Graduate members of today who have secured their ND Agr E or its equivalent and have been pledged a protected career-linked avenue to I Agr E corporate membership, would willingly see this avenue destroyed. Constituent membership of CEI would also require the Institution to withdraw the designatory initials of 'AI Agr E' from all present and future Associates. This in itself would reduce the attractiveness of that grade to the hundreds of loyal and enthusiastic members who currently pride their status as Associates of our Institution. In all these circumstances, it is doubtful whether the Institution could remain a viable entity at all, let alone be in the position to apply independently for constituent membership of CEI.

Despite these formidable deterrents, your Council decided that it must leave no avenue unexplored by which agricultural engineering could acquire CEI recognition. The possibility of merging the Institution with an existing constituent member of CEI was seriously studied. A Joint Working Party was set up in 1968 with the Institution of Mechanical Engineers, a body with which our Institution has long enjoyed close ties of kinship. I Mech E was quite willing to investigate this possibility, in the same way that it had done with other non-chartered institutions. Here again however I cannot conceal from you that we ran into difficulty. It came to be acknowledged that elements of incompatibility were inherent in the I Mech E/I Agr E situation, primarily because of the complex inter-disciplinary structure of our industry. **It has to be clearly understood that there is not the remotest possibility of a guaranteed grade-by-grade merger, resulting in all corporate members of our Institution being granted chartered engineer status. Only those members holding acceptable qualifications would be so admitted.**

The two Institutions therefore wisely decided to learn the lesson of history and avoid a breakdown of negotiations. I Mech E and I Agr E issued a joint public statement in 1968 saying that amalgamation was not envisaged but that co-operation between them, directed at enhancing the status of agricultural engineering would continue. At the same time, I Mech E acknowledged the contribution of I Agr E in the field of agricultural engineering and mechanisation and gave undertakings of friendly support. A good example of this is the joint I Mech E/I Agr E Symposium on "Agricultural and Allied Industrial Tractors" to be held in London in October 1970.

Against the background of everything I have so far described to you, the Council came overwhelmingly to the conclusion that some form of association with CEI, short of actual constituent membership, was the correct objective. To assist its attainment, the I Agr E membership structure was reframed to allow the 'degree-level' and 'diploma-level' streams to be more readily identified. One purpose of this was to build the I Agr E end of a bridge and stimulate the motivation for the other end to be built by CEI itself.

I am delighted to be able to tell you that the prospect of building this bridge is likely to become a reality in the near future, by means of our Institution becoming an Affiliate Member of CEI. The Board of CEI has let it be known that applications for such affiliate membership by suitable institutions will be actively considered and I Agr E has been specifically notified of this fact.

Although the full details of affiliate membership have still to be worked out, it will certainly have the advantage that the Institution would not be inhibited by the formidable regulations governing constituent membership. Our own membership structure will be able to continue on its present basis, both at corporate and non-corporate levels. Affiliate membership on the other hand would not forever close the door to eventual constituent membership if, in changed circumstances, the Institution decided to pursue it.

There is already a broad acceptance that our Membership (MI Agr E) grade falls within the outline standards that are confidently expected to form the basis for a new national title for technician engineers under the proposed composite register. It has been established beyond all reasonable doubt that our Institution will be the recognised body for sponsoring diploma-level agricultural engineers via our Membership grade for such registration.

Another level of national qualification and title is to be established for engineering technicians. Broadly speaking, this is likely to be centred around the level of attainment and ability represented by an Ordinary National Certificate or an intermediate City and Guilds qualification. Many of our Associates fall into this category and it is virtually certain that those Associates who can meet the requirements, when they are eventually established, will be able to register.

There is also a broad acceptance of the fact that our Fellowship (FI Agr E) grade falls within the outline standards of degree-level ability that are pre-eminently necessary for registering individuals as chartered engineers. I wish I could say to you that I Agr E affiliate membership of CEI would immediately enable our Fellows to register for the title C Eng. CEI acknowledges this to be a problem in certain non-chartered institutions, of which I Agr E is one, and has agreed that this problem must be discussed and, in due time, solved. In this respect, our negotiations with I Mech E are being conducted upon an optimistic note, and these will continue. Our affiliation to CEI would undoubtedly add strength and weight in our joint endeavours to find a solution.

Let me now summarise the position. I have tried to indicate to you why I feel that the Institution, based as it is upon a network of inter-acting engineering and science disciplines, is not well-placed to take advantage of constituent membership of CEI, either as an individual body or by merging with an existing constituent member. To force the Institution into such a mould would, in the opinion of your Council, restrict and over-simplify the role of agricultural engineering to the point where it might entirely lose its separate identity.

Affiliate membership of CEI would, on the other hand, conserve the Institution's separate identity and would complete the bridge to CEI that I Agr E, in common with several other reputable non-chartered institutions, has long awaited. In my view, direct affiliation to CEI will stabilise the role of agricultural engineering in our society.

I have spoken of this link with CEI as a bridge, across which we shall hope to usher our suitably qualified members to their rightful place in the sun. But I like to think that this bridge will also carry a two-way traffic of ideas, in a steady flow of friendship and co-operation from core to perimeter of the engineering profession. The world needs such bridges. I ask you now to help CEI and I Agr E in this exciting undertaking by making a special effort to attend our Annual General Meeting to be held at I Mech E, London on 12 May 1970 at 10 00 am and giving your support to the following resolution:—

> **That the Council of the Institution forthwith enter into direct negotiations with the Council of Engineering Institutions (CEI) with a view to affiliating the Institution to CEI on such terms and conditions as shall be mutually acceptable to the Institution Council and the CEI Board of Management, to the end that such national qualifications and titles as are or shall hereafter be required and bestowed by authority of the Charter of CEI shall extend to include members of the Institution who are suitably qualified.**

We are inviting a senior representative of CEI to be present at the AGM when this is discussed, to answer questions about affiliation with CEI and generally to help us gain a clear picture of the situation. Also available are some Notes prepared some while ago by Mr. J. H. W. Wilder, a Past President of the Institution, which set out very clearly and precisely the philosophy which has guided your Council over recent years to the present situation. Copies of these notes can be obtained on application to the Institution Secretary, Jon Bennett, or to your local Branch Honorary Secretary.

Do come to the AGM and give us your support.

Yours very truly,

President

March 1970

6 - 7 October, 1970

A Date for your Diary

THE INSTITUTION OF MECHANICAL ENGINEERS
(Automobile Division)
and
THE INSTITUTION OF AGRICULTURAL ENGINEERS
will hold a Joint Symposium on
AGRICULTURAL & ALLIED INDUSTRIAL TRACTORS

At I Mech E, 1 Birdcage Walk, London S.W.1. Full details to be announced soon.

PUBLICATIONS

The following books, papers and data have been received or noted by the Institution.

CIGR Congress 1969

The Reports and General Subjects of the 7th Congress of Commission Internationale du Genie Rural held in Baden-Baden from 2-6 October 1969 have been reported in eight volumes obtainable from the publishers, Commission Internationale du Genie Rural, 19 Avenue du Maine, Paris 15e, France.

Each volume is printed in French, German and English.

Fuels and Lubricants in Agriculture—by J. D. Savage and P. B. Bostock, The British Petroleum Company Ltd.

The paper deals with two principal topics, of which the first is the rationalization of lubricants. The authors claim that the use of different oils in different parts of modern tractors and mechanical farm equipment in general has complicated servicing and maintenance procedures and has led to poor storage conditions due to the problem of housing several cans and drums of oil for a small range of equipment. The confusion that arises from a multiplicity of grades can lead to serious damage from the use of the wrong oil. In Europe, this disadvantage has been overcome by the use of multi-purpose oils suitable for use in engines, transmissions and hydraulics of tractors and in most other farm machinery. The paper shows the extent to which oils of the 'universal' type can be used in agricultural equipment and points out the particular applications in which specialized oils really must be used.

The correct handling and storage of tractor fuel is the second topic. During the past few years the authors have had the opportunity to study the effect of proper fuel storage facilities in the operation of a mixed and dispersed fleet of tractors in Scotland. The primitive conditions that existed initially had led to frequent breakdown, considerable loss of working time and expensive repairs. By providing simple, but technically sound, storage and handling facilities, time lost due to dirty fuel has been completely eliminated. The lessons learned from this exercise are directly applicable to any agricultural area, but apply particularly in developing countries where the value of adequate fuel storage and handling facilities is frequently under-estimated.

The Main Library of Today and its Brief History—by the Cracow College of Agriculture, Poland.

A 22-page booklet gives the history of the extensive library facilities at The College of Agriculture in Cracow (printed in English). Copies of Scientific Papers (Numbers 4, 10 and 15) have also been received (printed in Polish).

Parliamentary Reports and Abstracts—by the Industrial Advisory Bureau.

The Bureau announces details of its fortnightly Parliamentary Reports which are issued under the following headings:

Housing and Building.
Agriculture and Food Production.
Economics and Industry.
Export Policy.
(The Report covering Transport and Shipping is temporarily suspended).

The Reports are issued on the 1st and 15th of each month while Parliament is in session. They are intended for the busy executive who wishes to be kept informed of the significant Questions and Answers and relevant debates in the House of Commons. Subscription rates: £4 4 0 per subject per annum. Specimen copies: 2/-.
Available from IDB at 10 Upper Berkeley Street, London W1.

Using a Fluorocarbon-Resin Film as a Coating for Seed-Roll Boxes—Its Effects on Gin-Stand Capacity, Seed-Roll Density and Rotational Velocity—by the Agricultural Research Service, US Department of Agriculture.

The objective of this research study was twofold:

1. To determine, by measuring the seed-roll's density and tangential to velocity, if coating the seed-roll box of a gin-stand with Teflon would produce a measurable effect of gin-stand capacity and operation, and on lint quality.
2. If the first experiment produced a significant effect, to conduct a second experiment to obtain a quantitative measure of the increase in gin-stand capacity.

BOOK REVIEW

Workshop Theory by Vincent Austin

(Macmillan 25/-).

The above book sets out to cover Engineering Workshop Theory and Metalwork for CSE 'O' and 'A' level GCE examinations. Although this is an extremely competitive field and there are a large number of books on this topic, this particular publication does make a useful contribution and it provides an interesting approach particularly in some of the line diagrams indicating workshop processes. Those dealing with forge work and sheet metal work are particularly useful. On the other hand, some of the illustrations showing items of equipment, e.g. the blacksmith's forge, a pillar drill and the hand drill, contribute little. Inevitably, due to the wide range of subjects included in the book, treatment of some subjects such as welding and metallurgy are superficial. However, the inclusion of typical examination questions, at the end of the book, should prove extremely useful for examination candidates.

To sum up, it is doubtful whether the book could be used exclusively by candidates for GCE and CSE examinations but it should make a useful contribution and provide a valuable source of reference with respect to the subjects which it covers in detail.

J.C.T. □

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★ **Traction control (implement weight transfer)—1953.**

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★ **All-purpose tractor hydraulic system with single lever control—1959.**

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NEWS FROM BRANCHES

East Anglian Branch

The Branch held its Annual Dinner at Ipswich on 20 February. A warm welcome was extended by the Branch Chairman, Mr T. J. Rivers, who proposed the toast of the Institution.

The response was made by the President of the Institution, Mr H. C. G. Henniker-Wright. In his speech, he described the progress that had been made in negotiations directed at drawing the Institution into a closer association with the Council of Engineering Institutions. He applauded the efforts of CEI to improve the status of the engineer in society and said that, in his view, Britain would be better placed to compete in the *world* if more engineers of top quality were in positions of authority. CEI was probably the only body which could bring this about. At the same time, it was essential to define the future role of agricultural engineers in the situation created by the existence of CEI. The industry would be well served by I Agr E, an integrated, industry-based Institution, in which chartered engineers, technician engineers and associated non-engineers, could play their part.

CEI was now formulating its Rules for Affiliate Membership by suitably qualified institutions. Every member of the Institution would shortly be receiving a Presidential Letter explaining what affiliation was about, why it was believed that it could be the answer for this Institution and stabilize agricultural engineering in society for a long time to come. The President hoped as many members as possible would come to the AGM in London on 12 May 1970 because on that date a Special Resolution was being put, to give Council a mandate to negotiate directly with CEI so as to affiliate the Institution to them.

It was a matter of building a bridge between industry-based institutions and CEI and it was something that a number of reputable industry-based institutions, including I Agr E, had long awaited. It should be a bridge carrying a two-way traffic of ideas, of friendship and of co-operation from one end of the engineering profession to the other. The world needed such bridges.

The President said it had taken a long time and a lot of patient negotiation to arrive at the point where these matters could now be openly discussed. He hoped members would see in this exciting situation the possibility of agricultural engineering being stabilized in society as an established and recognized sector of twentieth-century technology.

West Midlands Branch

'We have moved into the same sphere as the combine harvester where we need no more than a team of tractor drivers to harvest and haul to the store', said Mr W. J. Whitsed of Root Harvesters Ltd, at a meeting of the West Midlands Branch held at Halesowen, Worcestershire, on 2 February.

The heart of the machine was an electronic separator which accepted potatoes and rejected stones and clods. This was mounted in a Whitsed Super Duplex Harvester which dealt with lifting, soil separation and trash separation in the normal way.

The Whitsed Electronic Potato Harvester in action.

The electronic separator had distinct advantage where there was a large proportion of stone and clod in the soil but, Mr Whitsed emphasized, any potential customer for a potato harvester would gain great benefit from careful consideration of all the factors which relate to his own particular requirements by making sure that the machine he bought would do what was claimed for it and gave him something approaching the results he was looking for on his land.

A pendulum-controlled cradle carried the presentation or delivery belt and the three prime units of the electronic separator; an X-ray source, a transistorized detector unit and a pneumatically operated nylon finger bank. Discrimination between potatoes on the one hand and stones and clods on the other was achieved by dropping these materials through a horizontal plane of sixteen X-ray beams. Interruption of any one of these beams by stones or to a lesser extent by clods would be sensed by one of the sixteen 'eyes' of the detector unit. This in turn would then trigger the pneumatic mechanism to open two of the seventeen separating fingers situated immediately below and permit stones and clods to be returned to the ground at the front of the machine.

Commenting on some aspects of operation, Mr Whitsed said that his Company had offered training facilities to drivers because of the complexity of the machine. Whereas the self-levelling feature of the electronic separator was automatic, permitting work on gradients up to 1 in 6 and sideling ground of up to 1 in 9, the driver's task is to control the volume and trajectory of material passing through the separator in addition to the normal tasks of operating the harvester. □

BSI NEWS

The following information has been made available by the British Standards Institution.

Metric Rod Links for Root Crop Harvesters

The British Standards Institution has published metric versions of two Standards specifying rod links for use in root crop harvesting machinery. The rod links interconnect so as to form an endless elevator which runs on sprockets and is used to convey the harvested crops within the machines.
The new Standards are BS 4026: *Rod links for root machinery: Part 3: Potato elevator diggers and main elevators on complete potato harvesters,* and *Part 4: Carrot and sugar beet harvesters.* They cover the same types of rod links as Parts 1 and 2, respectively, which are in inch units and will co-exist for as long as required.

Parts 3 and 4 have been prepared principally for the benefit of designers who are now contemplating the production of machines to metric dimensions.
A complementary aim of the comittee responsible for this work was to standardize main dimensions and the quality of material used for rod links. The adoption of this Standard will afford some degree of interchangeability and help to reduce the range of rod links required to be held by dealers.
Copies of BS 4026: Parts 3 and 4 are available from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price of each part is 6s (7s including postage to non-subscribers).

Changes in International Standards Organization

Changes in the internal structure of the International Organization for Standardization (ISO) to provide a more efficient framework for handling the increasing load in international standards harmonization have been announced in Geneva. The statement coincided with a change in the Council which concerns the UK member body, the British Standards Institution.

The ISO Council has recommended for ratification by member bodies the formation of four technical divisions for a trial period of two years. The divisions proposed are:

Division 1: Mechanical Engineering.
Division 2: Agriculture.
Division 3: Building and Building Materials.
Division 4: Transportation and Distribution.

It is anticipated that the composition of the divisions will be fairly flexible so that the technical committees coming within a particular division can be changed as the situation may require. It is proposed that each technical division shall have a Divisional Consultative Council, consisting of international experts in various fields, which would act as the advisory bodies to the Council in planning, organization and co-ordination.

Accompanying these structural proposals are revised directives for the technical work of ISO, designed to assist the speed and scope of standardization.

After his second successive term as vice-president of ISO, Mr Roy Binney, director-general of the British Standards Institution, steps down in favour of Dr Reza Shayegan, director-general of the Iranian standards body. This does not affect Mr Binney's position on ISO's Council and its Executive Committee, where policy decisions are taken. Mr Binney is the longest-serving member of the Council and extremely active in international affairs in this field: Dr Shayegan, the new vice-president, was formerly Dean of the Institute of Technology of Tehran and has lectured in chemical engineering in the United States.

Standards Course at Bath

A three-day Standards Course sponsored by BSI and the Bath University of Technology Centre for Adult Studies, was held in Bath from 18–20 March 1970. It was designed for Standards engineers or those responsible for Standards work in their companies or organizations, to bring them up to date on standardization matters, to review the general principles of their work, discuss their problems, and exchange ideas.

The course consisted of lectures and discussions on product variety control; quality control; the computer as a tool for the Standards engineer; coding; information retrieval; the role of BSI and international standardization; the management of a standardization policy, and standardization and costing.

Students were invited to contribute short case studies on the change to metric.

British Standard for Agricultural-Type Respirators Withdrawn

The British Standards Institution has announced the withdrawal of BS 2617, the British Standard which specifies respirators for agricultural workers using toxic chemicals.

The reason for this withdrawal is that the Ministry of Agriculture, Fisheries and Food considers that the 1969 revision of BS 2091: *Respirators for protection against harmful dust and gases* fully meets the requirements previously fulfilled by BS 2617. An amendment to BS 2091 will make clear this increase in its scope.

The Ministry of Agriculture, Fisheries and Food was directly represented on the committee which prepared BS 2091.

Copies of BS 2091 can be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price 12s each (14s including postage to non-subscribers).

Portable Screw Conveyors

Guarding and safety requirements are given special attention in BS 4409 *Screw conveyors Part 2*: 1970, *Portable and mobile tubular type (Augers) for agricultural and light industrial use,* which is now published. This part of the standard specifies dimensions for portable and mobile screw conveyors constructed of mild steel in sizes from 100 mm to 250 mm nominal diameter.

In the interests of safety the parts of the machinery which require guarding are listed and the form of guard specified. Stopping and starting devices are included. An appendix provides a list of statutory provisions affecting conveyors to be used in the United Kingdom.

Other factors dealt with are stability, intake and flow control, prime movers, suspension and positioning.

Copies of BS 4409, Part 2, may be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price 8s (10s to non-subscribers including postage).

BSI Forges Ahead With Modular Machine Tool Units

The British Standards Institution is pushing ahead as fast as possible with vital national and international work on the standardization of unit construction machine tools in metric dimensions—work which will eventually lead to economies in design and production of equipment used throughout manufacturing industry.

Current work on unit construction machines will have particular significance for the motor vehicle manufacturing industry, one of the main users of this type of equipment. In the not-too-distant future, the industry will be assured of complete interchangeability in respect of interface characteristics between machine tool units manufactured in this country and abroad.

At present, work being carried out under the auspices of the International Organization for Standardization is focused on the preparation of recommendations for standard dimensions of units heads used in drilling, reaming, milling and other operations together with related slide units, wing bases, and columns and a Working Group on this subject consisting of 20 delegates from France, Germany and Britain met for the second time at the end of January at the BSI headquarters in London.

At the meeting, it was decided to seek authority to enlarge the scope of the Working Group's programme to include multi-spindle heads and also to extend the previously agreed range of slide units to include the smaller nominal sizes of 125, 160 and 200 mm.

This particular meeting principally concerned slide units and agreement was reached on certain principal dimensions, namely, the width over the bolting down flange; the distance between the rows of holding-down bolts together with the related thread diameters and clearance holes; a system of pitching individual bolt holes in each row; the lengths of the saddle expressed as a ratio to the nominal width of the unit; and the length of the slide base.

A specific range of saddle strokes was adopted despite strong representations by the UK members of the Working Group on behalf of British industry, who wanted certain minimum strokes only to be defined. The UK is at present considering its position on this matter.

The Working Group was unable to agree on the choice of a range of heights for slide units due to the German Member Body maintaining its position with regard to the use of the Renard series of preferred numbers and also the practice of having a different height for each given width of slide unit. The UK is also considering its position on this matter.

If the UK finds it is unable to accept the position in respect of the heights of slide units, the matter will be referred to the main ISO machine tool committee for its decision.

It is intended that the Recommendations of the ISO Working Group will eventually be adopted as the basis for national standards by the member bodies including BSI.

Tests for Diesel Engine Fuel Filters

The British Standards Institution has published the first part of a new British Standard which specifies tests for the performance of fuel filters for compression-ignition (diesel) engines—BS 4552: *Fuel filters for compression-ignition engines: Part 1: Determination of pressure differential/flow characteristics and initial particle retention.*

The Standard applies to engines which use diesel fuel (gas-oil) complying with BS 2869 classes A1 and A2 but, if agreed between manufacturer and purchaser, it may be applied to filters used with other fuels.

The first test specified in Part 1 is for measurement of the pressure differential across the filter at the filter manufacturer's rated flow, or at a rate of flow agreed between the purchaser and the manufacturer. The purpose of the second test is to measure the percentage retention of a specified test dust through a filter under a set of controlled conditions. This test is used to determine the characteristics of the filter element both under normal conditions and when contaminated with water.

Parts 2 and 3 of this Standard, which are in course of preparation, will deal respectively with 'Determination of life and variation in particle retention' and 'Tests for water separation'.

Copies of BS 4552: Part 1 may be obtained from the BSI Sales Branch, 101/113 Pentonville Road, London N1. Price 10s (12s to non-subscribers including postage).

Testing of Engines Used in Agriculture and Forestry

Engines used in agricultural and horticultural work have to be capable of operating under a variety of adverse conditions. A standard testing schedule is given in the new BS 4539: *Methods of testing small spark ignition engines for agricultural use,* which is now published. This is one of a series of British Standards on the performance of internal combustion engines.

The new standard provides methods for testing engines used in agriculture, horticulture and forestry, but excludes engines which are not functionally self-sufficient. Opening clauses deal with selection and preparation for testing, running-in procedure and maintenance, accuracy of measuring equipment, the test fuel, standard operating reference conditions, and numerous power output tests. The clause on starting tests specifies a start under hot, cold and damp conditions. A three stage endurance test is specified which includes a test with the engine tilted, and a test in moderate density dust conditions to establish the effectiveness of the air cleaner and the resistance of the engine as a whole to ingress of dust.

Optional tests for high density dust conditions, high and low temperature conditions and subsidiary power take-off are given.

The clause describing the submission of test results refers to a complete specimen report laid out in an appendix. It requires that curves of torque, power output, fuel consumption and specific fuel consumption be represented for the different engine speeds. Another appendix shows typical test curves for the endurance test.

Copies of BS 4539 may be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N1. Price 14s (17s including postage to non-subscribers). □

THE ASSESSMENT OF WORK LOAD IN AGRICULTURAL TASKS

by R. W. TOMLINSON, BSc, MSc, PhD*

Presented at the Autumn National Meeting of the Institution at Loughborough University of Technology on 4 September 1969

1. Introduction

An idea of the importance of physical work load assessment can be gauged from work done by Lehmann.[1] He found that workers took camouflaged rest pauses, i.e. pauses with light accessory work so that they appeared occupied. Output rose when more frequent rest pauses were introduced, since the camouflaged rest pauses and accessory work were reduced. In the physiological sense also the camouflaged rest pauses were less efficient because they allowed much less physiological recovery than a true rest pause.

Christensen[2] proposes the classification of physical work levels given in Table 1.

TABLE 1

Scaling of physical work

K cal/min		Heart rate
12·5	Unduly heavy	175
10·0	Very heavy	150
7·5	Heavy	125
5·0	Moderately heavy	100
2·5	Light	75
	Very light	

The heart rate criteria may be very misleading since wide variations exist between subjects and also with degree of fitness. Passmore and Durnin[3] consider that these levels are only appropriate for work of a few minutes duration; longer schedules are a different matter. Lehmann[1] considers that 5 K cal/min (including a basal metabolic rate of about 1 K cal/min) is the maximum consistent level that a worker should be expected to expend, i.e. more rest pauses should be included if the average level exceeds this value. For severe physical work, frequent, short rest pauses are better for physiological recovery than infrequent, but longer, rest pauses. At the individual level, Christensen[2] considers that a task should not require more than half the maximum energy expenditure of which a worker is capable. Presumably he refers to the maximum consistent energy expenditure since short term values can be very high. These maximum levels can be predicted without the need for maximum exertion.[4]

As pointed out by Christensen,[2] severe physical stress may be encountered at much lower levels of physical effort than those cited above if:

(i) It is predominantly static in nature;
(ii) The environmental temperature is high;
(iii) The posture is awkward and unnatural;
(iv) The muscular groups involved are relatively weak.

The economic effects of mental stress may be even more serious than those of physical stress. It is estimated that one third of sick leave in many countries is due to mental conflicts,[5] many of which may be due to some element of job dissatisfaction. Apart from sick leave, similar considerations are believed to be significant causes of high labour turnover.[6] An excessive level of mental work load may also be a contributory factor of accidents and loss of production through inefficient use of time as well as wastage in material.

*Tractor and Ergonomics Dept., National Institute of Agricultural Engineering.

2. Review of Methodology

2.1 Physical Work Load

2.1.1 *Respirometry*

The conversion of carbohydrate, fat and protein into energy is an oxidation process so that from oxygen consumption (i.e. differences between inspired and expired air samples) the caloric equivalent can be calculated.[7,8] Although this equivalent is dependent upon the proportions of carbohydrate, fat and protein oxidized, an average value has been shown to give accurate results. About 20% of the caloric equivalent appears as mechanical energy, the larger part being dissipated as heat. From this information, physiologists have deduced equations from which energy expenditure can be calculated from the oxygen consumed and the volume of air expired.

Generally, therefore, the most accurate assessment of physical effort is the measurement of oxygen consumption and this is afforded by a respirometer such as the Kofranyi-Michaelis respirometer.[9] This consists of a face mask from which the expired air is fed to a flow meter carried on the back of the subject. Limits on its accuracy exist for high rates of expiration (50 litres/min), in the case of static work, and also since energy may be supplied by the formation of lactic acid.[2] Its main disadvantages are its size, which can prohibit easy movement and also contribute significantly to the level of work load, and the resistance to breathing, which some subjects find unpleasant.

A further disadvantage of respirometry is that, for accurate analysis of the expired air, a sample must be collected over several minutes. Experience of work study practitioners, however, has shown that work methods, operation times, weights of materials employed and other factors may vary so that the sampling period subsumes a number of task variations. In certain cases these may be of primary interest, and the only alternative to a simulated task with a prohibitively extensive experimental design is to accompany the respirometric measurements with some method of task description. Zenz and Berg[10] have described modifications to the respirometer that would accomplish this. A small oxygen sensor is inserted into the stream of expired air. This permits instant read-out of oxygen content and, coupled with a telemetry system (e.g. Krobath and Reid[11]), would allow observation of this without interference with the operator. The volume of expired air recorded on the mechanical counter is photographed by a portable camera fixed to the respirometer. The obvious disadvantage is the increased size of the apparatus. Aberg *et al*[12] have developed a model for the prediction of energy expenditure from basal metabolism and physical measurements, e.g. movement type and extent, posture, and the forces involved. Surprisingly high accuracy was obtained with some tasks but accuracy deteriorated for other tasks.

Despite its limitations, respirometry is the standard technique of physical work load assessment in that other methods of measurement depend upon it as a reference with which to convert values into meaningful units of energy expenditure.

2.1.2 *Heart rate*

Since the body fuels are carried to the muscles by the bloodstream, an increase in energy expenditure is accompanied by an increase in heart rate. The stroke volume of the heart may also increase, but this effect is secondary[13] so that a clear relationship between heart rate and energy expenditure usually exists,[2,4,13] although Booyens and Hervey[14] concluded that for very light work the variability of heart rate is too great for it to be a satisfactory measure of energy expenditure. The relationship between heart rate and energy expenditure is disturbed if the environmental temperature is high, if humidity is high or if excessive clothing is worn. Although the effect of heat load on heart rate is well established, studies of its influence on energy expenditure have produced contradictory results. Le Blanc[15] found no effect of environmental temperature on energy expenditure having studied temperatures appropriate to temperate, arctic and sub-arctic regions. Passmore and Durnin[3] reviewed the work of several authors and came to the same conclusion. However, although the total range covered by these authors was —16°C-49°C, each study considered only small ranges of 20°C or less so that it is difficult to draw an absolute conclusion. Later, Durnin and Haisman[16] studied hot (39°C-44°C) and temperate (22°C) conditions and found a 10% increase in energy expenditure for hot conditions with little difference between hot conditions with low or high relative humidity. Despite this, it is known that in hot environments the heart rate calibration procedure considerably over estimates actual energy expenditure. Edholm *et al*[17] consider that once the worker is acclimatized to the heat, then heart rate may be used to estimate energy expenditure if corrections are made for the rise in body temperature. Conversely, heart rate is the most useful measure for the assessment of heat stress, particularly if radiant in nature.[1,18]

The relationship between heart rate and energy expenditure also breaks down for very high work levels,[19] heart rate levelling off at a rate of oxygen uptake dependent upon the subject's fitness. With training, the stroke volume of the heart increases and given blood flow can be attained with less increase in pulse rate. Unsatisfactory working postures and static work also lead to disproportionate increases in heart rate relative to oxygen consumption[20,21] and, likewise to heat stress, heart rate is a better metric in these cases. A high pulse rate associated with relatively low oxygen consumption is especially indicative of muscle fatigue, particularly due to static work.[1]

Finally, emotional stress will also interfere with the use of heart rate as a measure of oxygen consumption.

2.1.3 *Ventilation rate and frequency*

Many physiologists have found the gas analyses associated with oxygen consumption measurements to be disadvantageous because of the time taken. Since this reduces the number of measurements that can be taken, experimental error is likely to increase. A number of workers have therefore dispensed with gas analyses and measured ventilation rate (volume/min). Ford and Hellerstein[22] used ventilation rate on groups of subjects whose ages ranged from 18 to 66 years. Regression or calibration lines were calculated for the groups and not for individuals so that a relatively high percentage error was obtained. Sartorelli[23] and Durnin and Edwards[24] used individual regression lines and obtained higher accuracy, the accuracy depending upon the number of observations made during the calibration procedure.

Errors arise in the use of ventilation rate for predicting energy expenditure if the work is very light or very heavy. For light work, as with heart rate, measurements are much less stable while for heavy work the ventilation rate tends to level off although oxygen consumption continues to increase. Durnin and Edwards[24] suggest that rates between 15 and 45 litres/min are satisfactory. The regression line does not pass through the origin[22,24] and, if it is so drawn, error will arise. A further differential error between studies arises when the dead space volumes of the face mask and ancillary apparatus vary.[22] The disadvantage of the face mask both in terms of error and discomfort to the operator can be eliminated if ventilation frequency is measured using a bead thermistor attached to a spectacle frame.[25] Ventilation frequency, however, is likely to be less accurate since variations in the volume of inspired air per cycle are excluded.[26]

A more satisfactory alternative to the face mask technique is the use of strain gauge measures on the chest wall.[27] Variations in the size of the chest wall are sufficiently large for accurate measurements to be obtained, the peak-to-peak amplitude of the signals being a measure of the depth of respiration which is related to the volume of air breathed. The validation of this technique might be extremely useful.

Suggs and Splinter[28] found that ventilation rate responded to thermal radiation in much the same way as heart rate. Investigations of heart rate or ventilation rate for the estimation of energy expenditure have usually considered only one or the other and it is difficult to compare the techniques without introducing the bias of personal preference. However, Sharkey *et al*[20] have made a statistical comparison. The results were not clear cut in that the percentage errors in the estimates for the heart rate method were not statistically significant from chance, while those for ventilation were, although smaller percentage errors were evident for the latter technique. This statistical anomaly arose because there were much larger individual variations in the heart rate method and, on this basis, Sharkey *et al*[20] conclude that ventilation rates were the more accurate predictors. A limitation of this study is that only the laboratory tasks of cycling, static contraction and hand-cranking were considered. Comparative studies including field work are desirable.

2.1.4 *Calibration procedures for indirect calorimetry*

Screening of subjects should be carried out to exclude coronary cases and victims of pathological disease that could prejudice their safety.

Subjects should be in the post-absorptive state and the influence of stimulating beverages, cigarettes, recent exercise, and sleep should be controlled where possible. These considerations apply equally to field measurements. The author has found no reference to the influence of clothing on the accuracy of calibration. Excessive clothing when field measurements are carried out would presumably have the same effect on accuracy as excessive heat stress. Calibration is necessary for each individual although Andrews[29] believes that for large samples of workers an overall regression equation is sufficiently accurate. Three calibration tests have been commonly used, namely, the bicycle ergometer, repetitive stepping and treadmill walking. Differences in fitness between muscle groups may interfere with the accuracy of calibration[30] and since most practical tasks involve a significant, if not predominant, amount of movement of the upper limbs then such movements should be included in the calibrating activities. A bicycle ergometer with facilities for simultaneous hand and foot cranking appears, therefore, to be the most useful test.

The work of Booyens and Hervey[14] and Durnin and Edwards[24] indicates that measures of heart rate and ventilation rate for lying, sitting and standing are too variable for them to be satisfactory as calibration tasks.

Five or six levels of work load are usually determined by preliminary experimentation. A steady resting level for the measure in question must first be achieved. A subject then carries out the work task, a rest period being interspersed between each condition so that the original resting level is recaptured. After the onset of the work cycle there is a period of adaptation before a steady state response is achieved. For heart rate, investigators appear to differ on the adaptation time. According to Davies,[31] for moderate to heavy exercise, the abrupt rise in cardiac frequency is followed by a slower secondary rise to the steady state level. Similarly, the steady state for oxygen consumption requires roughly the same adaptation.[19] Billings *et al*[32] considered that heart rate adapted to the work level within one minute even for heavy work. In studies of heart rate calibration, Allen[33] has used adaptation times of three to four minutes, Booyens and Hervey[14] five minutes, and Malhotra *et al*[13] eight to nine minutes. A value of three minutes appears reasonable.

After the steady state has been reached, measurement of the oxygen consumption and the ventilation rate or heart rate should be carried out while the subject is in the steady state, since Burger[34] notes that within fifteen seconds after the cessation of work, heart rate drops by 7-10 beats per minute.

2.1.5 *Other physiological measures*

Christensen[2] considers body temperature to be a reliable indication of the heaviness of work, adaptation normally occurring after about one hour's work at a level dependent upon the work load. At high environmental temperatures, body temperature increases disproportionately to oxygen consumption, and, like heart rate, becomes a specific indication of heat stress. Aural and oral temperatures respond more quickly than rectal temperature to changes in deep body temperature.[35] Fluid loss, exclusive of urine, is likewise a good indication of thermal stress. Only a limited amount of heat can be produced by the body without the appearance of visible perspiration; heat production above this increases deep body temperature and sweating.[36]

Cold environments are a special problem with blood pressure the most suitable physiological measure. Heart rate shows little change for cold versus temperate environments whereas blood pressure will increase with falling temperature.[34]

An interesting concept has been proposed by Burger.[34] He argues that the physiological measures used in the past are dependent upon certain functional demands but not all. Thus, for example, oxygen consumption is not a reliable indicant of physical stress where thermal stress is a significant element. In many tasks such difficulties may not arise, but, where they do, Burger suggests the integrated measure of circulatory load. This is the product of heart rate, blood pressure and stroke volume changes expressed as ratios. The underlying logic is that changes in environment or nature of work will produce concomitant changes in one or more of the three elements of the integrated function, e.g. stroke volume increases for dynamic muscular work up to a certain level, when a steady state is reached, although heart rate continues to rise. Cold exposure will influence blood pressure but not heart rate or stroke volume. The concept of circulatory load is a recent one and requires validation; there may be a danger that measurements over a variety of conditions are not comparable without weighting factors, i.e. what change in blood pressure is indicative of equivalent strain to a 50% increase in heart rate. Subjective assessments may be the only means of deducing weighting factors. Another limitation is that only heart rate can be easily measured in field situations. Stroke volume is particularly difficult and it seems necessary to use pulse pressure as an index of stroke volume so that in fact only two elements are involved in the circulatory load metric. In field situations, measurement of blood pressure at present requires short rest pauses of about 15 seconds during which time blood pressure will drop slightly.

2.2 Mental Work Load

The assessment of mental work load presents a great challenge to the psychologist and psychophysiologist and, despite a plethora of techniques, few are of general applicability and those that are have question marks regarding their validity.

The following categories may be distinguished:
(i) Physiological responses;
(ii) Secondary task measures;
(iii) Measures associated with basic task performance.

2.2.1 *Physiological responses*

Michon[37] briefly reviews some physiological studies. Electro-encephalograms (brainwaves) have not produced satisfactory results. Electrical skin resistance is a difficult measure to control but Lehmann[38] has reported a successful study of emotional stress of vibration experienced on various tractor seats. Its use as a measure of mental stress, however, has not been validated. A promising method is the study of muscle potentials, for example of the neck muscles, since perceptual processing is believed to be associated with an increase in nervous tension with consequent increase in muscle tone. Validating studies are still awaited for this technique. However, the increase in muscle tone cannot be a general bodily effect since this would increase static work and likewise heart rate. In contrast, mental load has virtually no effect on overall heart rate.[34] Effects on energy expenditure have been reviewed by Passmore and Durnin[3] but consistent trends were not apparent and overall the effect was not significant. Perceptual load has produced changes in blood pressure[34] but, as mentioned earlier, blood pressure as yet cannot be measured while the subject is working unless the task allows the subject to be stationary. Pupillary dilation accompanies mental stress and Kahneman *et al*[51] believe this technique to be a sensitive indicator. Its applicability, however, is somewhat restricted, although fibre optics connecting a spectacle lens and a camera on the subjects' back have been used.[74]

For a resting subject the beat-to-beat intervals of the pulse rate are relatively irregular, a phenomenon known as sinus arrhythmia. If additional information processing requirements are placed on the nervous system, the irregularity decreases. For laboratory studies, Kalsbeek and Sykes[40] have demonstrated sinus arrhythmia as a measure of perceptual load. The disadvantage of this technique is the effect of physical effort on heart rate, the technique possibly being inapplicable where physical work is appreciable.

Plethysmography (involving measurement of the blood volume passing through the blood vessels at a given station) awaits evaluation. Since the nervous system responds to stress by shutting off peripheral blood flow, plethysmography should detect changes due to emotional stress and possibly due to perceptual stress. The standard technique for this involves a hollow, water filled cylinder, placed around the subject's arm but this impractical apparatus could be replaced with a compact device on a rigid base such as the forehead. Alternatively, a measure of amplitude could be obtained from the photocell method of monitoring heart rate, amplitude being related to blood volume.[41] A question mark against this method concerns the effects of physical work load on blood vessel dilation.

Analysis of urinary products has been used as a measure of emotional stress but only in the long term sense. Examples, such as studies of adrenaline secretion, have been the subject of discussion in a recent book.[42] Possibly mental stress may lead to similar secretory corollates.

A major problem with physiological responses is their validation when physical effort is appreciable. For this and other reasons, Lazarus[43] expresses qualms about the use of physiological measures for psychological processes. A further problem is the influence of response specificity. Lacey *et al*[44] applied various stresses, including mental arithmetic, to subjects, and measured skin resistance, heart rate and variability of heart rate. They found that a given subject's major autonomic (nervous system) response occurred via the same physiological function for all stresses. Since different subjects have different physiological functions producing the strongest response, it may be that a satisfactory physiological response to mental stress, if validated, would not be universally applicable with equal success.

2.2.2 *Secondary task measures*

The addition of a second task to the basic task leads to a series of measures.

(a) *Subsidiary task measures*

The basic premises on which these measures are based are that the perceptual capacity is limited and the addition of a second task may cause this capacity to be exceeded, this being more probable the greater the capacity demanded by the basic task. A characteristic of subsidiary task measures is that the basic task has priority, i.e. when the perceptual capacity is exceeded 'errors' must appear in the subsidiary task. The errors that arise give rise to the measure of mental work load for the basic task.

The theoretical premises upon which subsidiary task measures are based are open to debate.[45] The perceptual capacity may be fluctuating even when the basic task is performed alone; the addition of the secondary task may add to the fluctuations and raise or lower the overall level of capacity. Further, separate perceptual loads are probably not strictly additive. The basic premise underlying subsidiary task measures may be restated as the concept of a limiting, single channel processor in the higher nervous centres. Adams and Creamer[46] consider this to be applicable only to information associated with uncertain events, i.e. where anticipation is not possible.

Individual differences in ability to carry out the secondary task introduce variability into the results so that the performance of each subject on the secondary task when it is in combination with the basic task should be corrected in relation to his performance on the secondary task alone. A further disadvantage is that the error measure for the secondary task is an arbitrary unit of perceptual load so that comparisons between studies using different secondary tasks cannot be made. Ideally, conversion into a recognized measure of information processing is required but generally this cannot be realized at present.

Some measure of performance on the basic task is required to check that the subject is not sacrificing performance on the basic task in achieving effective performance on the secondary task. In the studies of Brown of car driving[47] average speeds as well as movement reversals of the controls were measured.

The interference of the secondary task with the basic task should be in the higher centres of the brain rather than at the receptors or effectors, for example, tasks relying largely on the visual sense should not be studied via secondary tasks based on the visual sense. Further, Michon[37] points out that the secondary task should not interfere functionally with the basic task, for example, a secondary task involving mental arithmetic should not be combined with a basic task involving numerical assimilation.

Introspectively, one feels that a secondary task will be more effective the less the artificiality that it introduces, i.e. it should be 'built into' the basic task. This, however, seems a false hope. Assuming that a secondary element could be built into all parts of the basic task, convincing the subject of its importance and at the same time emphasizing that error should be biased towards the secondary element would appear to be mutually exclusive.

Two categories of subsidiary task may be differentiated:

(i) Motor tasks, as in Michon's[37] study of variability in rate of key-tapping, or the study of Brown *et al*[47] using a similar technique based on verbal responses;

(ii) Responses to programmed tasks, usually presented by tape recorders. Brown's[48] use of 8-digit groups is one example, Kalsbeek's[49] tones another. Programmed secondary tasks may be attention tasks or short term memory tasks.[50] Memory tasks should be very short term since otherwise an error made within the short term memory time span could be due to one or more of many factors. Another version of a programmed task is a vigilance task. Vigilance tasks are usually visual but this technique is not applicable to all work situations and is generally very time consuming.

The measure with subsidiary tasks may be either omissions of responses or reaction times. However, where reaction times are used few omissions should be allowed since one cannot relate the two. For programmed tasks requiring verbal responses, reaction times have the disadvantage of laborious analysis.

(b) *Loading tasks*

When used as a loading task, the secondary task is not subsidiary. A level of required performance on the secondary task is set so that if errors or delays must be committed they appear in the basic task. Brown[45] states that 'in general, loading tasks will be used where criteria of perceptual load are to be based upon the effectiveness with which the man handles information in the system and subsidiary tasks will be used where criteria are to be based upon the man's effort or efficiency'. Obviously the level of perceptual effort required to perform the loading task should not be so great that the basic task breaks down completely. Brown[45] quotes studies of loading tasks.

(c) *Stressing tasks*

If the basic and secondary tasks have common input channels into the organism and common output channels, the secondary task is known as a stressing task.[45] Presumably, measures may be obtained with the secondary task acting as a subsidiary task or as a loading task.

Secondary tasks may change the motivation of the subject but, despite this limitation and those mentioned earlier, secondary tasks may be the only practical method in many situations for assessing mental work load. They would appear to have particular promise as a measure of learning in predominantly perceptual tasks, i.e. tasks with information processing requirements.

2.2.3 *Measures associated with performance of the basic task*

Objective techniques

Eye movements have been studied, particularly with respect to pilots,[89] but the technique is of restricted applicability whether photographic observation or electro-occulograms are used.

The critical incidents technique may be applicable in certain cases. This involves the observation of incidents (errors) or near-incidents.[52] Mental overload *may* be indicated where relatively high measures are obtained with this method. A variation of this technique involves the measurement of operation times for the various elements of the work task. A high variation in these elemental times may be indicative of mental stress. The difficulty here is the accurate measurement of the elemental times; it is sometimes difficult to decide exactly where one element ends and the next begins. For long term elements, however, this is not a serious problem but the technique is applicable only to repetitive routines.

Operator rating

In a study by Bartenwerfer,[53] workers were asked to rate their own job in relation to a series of jobs ranked on a scale system. Workers in the same category showed substantial agreement. Bergstrom[54] requested his subjects to rank the 'experienced stress' in a simulated pilot-tracking task. Both task-induced stress (Morse interpretation as a secondary task) and distraction stress (light flashes) were used. The input rate for each was varied and the technique of magnitude estimation was used, a standard task being assigned an arbitrary value of 100, so that one requiring subjectively twice the mental effort would be rated 200. Errors on the secondary task were approximately linearly correlated with estimations of experienced stress.

Operator rating may be very useful particularly as a subsidiary measure to an objective measure.

Subjective measures via task analysis

Siegel *et al*[55] list ten factors leading to optimum information transfer in a system, e.g. appropriate redundancy of information, minimum time stress. The application of the DEI (display evaluative index) technique involves the symbolic representation of information transfers within the system. The links on this transfer chart are then coded according to the type of transfer. The links of the transfer chart are the basis for the calculation of the factors involved in the DEI, complexity, directness, number of display/control links, coding, time stress, criticality and the match between information supplied and information required all receive consideration in the overall formula for the calculation of DEI. Bainbridge and Beishon[56] suggest that repetitive actions and overall frequency of link transfers should have been included.

A second subjective technique is due to Kitchin and Graham.[57] They were concerned with devising a workable, industrial technique for assessing mental work load rather than one of great absolute accuracy. Initially, they considered eight classes of activity with important contributions to mental work load, e.g. control operations, memory, vigilance. Instances of these were scored on a points basis. The conclusion was, however, that as a practical technique of mental work load assessment, the procedure was over-complicated and uneconomic.

In the development of a simplified approach, it was realized that the common factor of most of the classes considered initially was a decision-making function, i.e. what should be done, how much of it, and when. Five categories of decision-making were nominated; number, complexity and interdependency of factors in the decision-making situation plus short term memory requirements and load due to delayed feed-back. Again points were allocated but the problem of frequency of occurrence noted in their earlier attempt was more realistically covered they felt by a weighing factor that increased in unit steps for much larger and non-linear steps in frequency of occurrence. Frequency was judged on the basis of action taken simply because it was the only practical basis of assessment.

They validated the results against the subjective judgments of the highly experienced workstudy practitioners involved in the study. Some success was claimed although results were not presented. An experimental validation of this technique against a more objective measure, such as secondary task analysis, would be a useful step forward.

2.2.4 *Mental strategies or models*

Bainbridge *et al*[58] have used a computer simulation technique for the study of operator decision-making and mental skill in an electric steel-melting shop where the basic process objective was the control of power to five furnaces. Inexperienced and experienced subjects were used and certain objective measures obtained for comparative purposes, e.g. number of power level changes, amount of power used. In this sense, the technique is reminiscent of the critical incidents technique mentioned earlier. For the analysis of decision-making, however, three conceptual models were considered:

(i) *Action/information tree model*
This assumes that the subjects have a prescribed set of objectives and sets of possible actions or strategies to fulfil these. A hierarchical tree is obtained with theoretically well defined links between each node or choice point where variable action is possible. Choice between actions is assumed to be resolved by information available at or prior to the node. This procedure broke down because, among other things, the well defined links were broken in practice, i.e. in fulfilling their objectives the subjects did not follow continuous paths down the hierarchy.

(ii) *Program models*
These involve possible decision routines again being hierarchical in nature, i.e. selection of a routine is dependent upon a higher level system or upon conditional entry requirements. The verbal reports of the subjects were used to identify routines. This model failed because of the complexity involved in assessing different sequences of routines and entry requirements.

(iii) *Thought stream analysis*
Analysis of verbal reports showed the existence of separate sequences of thoughts or thought streams. A stream may be carried through to completion or jumps may occur to another stream. The authors seem hopeful that further work will lead to a better understanding of the mechanism of control and initiation of thought sequences in specific situations, but the method seems to suffer from the drawback of the program model approach in that mechanisms will very likely be different from one operator to another, each requiring laborious analysis and making overall conclusions difficult to define.

The advantage of the mental model approach would be that it not only indicates where peak loads occur but also the underlying causes. The alternative methods really only offer to do the former, the basic causes being the postulates of the experimenter.

2.3 Fatigue

The concept of fatigue is one of the least well defined and most problematical facing the human scientist. Grandjean[59] makes the distinction that physiologists consider fatigue as a decrease in physical performance while psychologists consider the deterioration of mental and physical performance due to such factors as subjective feelings and loss of motivation as well as partial physical incapacitation.

Fatigue has many aspects and Browne[60] points out the search for a single measure of fatigue is a dream; the many aspects of fatigue require numerous different measures for their assessment.

Physiological fatigue may be accompanied by depletion of the carbo-hydrate reserves, which can be shown by measuring the blood-sugar concentration. In cases of heavy work, the recovery period of heart rate may be a suitable measure. Davies[31] points out, however, that accurate assessment of oxygen debt is difficult since a reproducible steady, basal level is difficult to obtain and lengthy rest periods are required before oxygen uptake returns to the control level, subjects becoming restless leading to fluctuations in oxygen consumption so that deciding when the control level is reached is difficult.

For muscular fatigue certain criteria are fairly well established. As mentioned earlier, a high heart rate associated with relatively low oxygen uptake is considered indicative of muscular fatigue particularly for static work. Lactic acid content of the blood has also been used as a measure.[2,61] If a consistent level of work is accompanied by an increase in heart rate Burger[34] considers that the increase is an index of muscular fatigue. Muscle fatigue can be assessed by observation of the size of the muscle action potentials (small electrical changes arising during the activity of muscles). As muscle fibres become fatigued, more motor units are recruited increasing the size of the action potential.[62] Further, it has been suggested by Knowlton *et al*[63] that the motor units recruited at the later stage of work have higher potentials than the motor units that have become fatigued. Posture and muscle fatigue are related and action potentials are useful in the study of posture.

Greater problems arise when mental components contribute to fatigue. Grandjean[59] and his co-workers have shown the variation in flicker fusion threshold throughout the work shift for air-traffic controllers. He notes, however, that flicker fusion measurements are open to many objections, for example, that application of the test may alter threshold levels; also the interruption of the work task may be a welcome break to the subject and thus have motivating effects.

Subjective self-rating of the feeling of fatigue may be a useful test particularly as a subsidiary to more objective measures. Grandjean[59] has also used this method in his study of air traffic controllers.

Subsidiary task studies may be useful, but their application requires care. There is a danger that the subsidiary task may contribute more to mental fatigue than the basic task itself. Thus, the subsidiary task should be used for one experimental period of the work shift and at no other time in that shift. The application of vigilance tests, in which omitted responses or response times are the measures, allows the task to be performed without interruption. The possibility always exists, however, that addition of the vigilance task or subsidiary task will change the motivation of the subject. This is an advantage for a method related to performance of the task itself, for example, Lehmann[1] considered that an increased time per work piece was an indication of fatigue. Care has to be taken with this sort of measure to avoid interference due to 'warm-up' and 'end-spurt' with respect to both the working day and intervening rest breaks. Murrell,[9] however, has shown that the irregularity of elemental times is a more sensitive measure than the mean. These techniques, however, will not differentiate between physical and mental fatigue.

3. Experimental Studies

3.1 Summary of Previous Research Work in Agriculture

The Purdue Farm Cardiac Project[64] covered physical work load in a variety of agricultural and horticultural activities including tractor driving, manure loading, milking, planting and harvesting. Dupuis[65] used respirometry and heart rate as measures in his study of tractor driving and work with implements. He also demonstrated substantial savings in energy expenditure for an 'optimized' seat and control arrangement. Lehmann[38] also considered tractor seat and control layout. Esmay and McGinty[66] studied silo tasks and pit-type milking using heart rate. Milking was also the subject of a study by Vos.[67] Respirometry was used by Hodges and Esmay[68] for the task of handling of hay and straw bales. They found marked differences in energy expenditure for different work methods. Troup[69] and van Loon[70] have studied forestry work. Combine harvesting has received some attention in a study by Zander.[71] Passmore and Durnin[3] quote some agricultural activities in their paper on energy expenditure.

The author knows of no published work on mental work load assessment in agriculture although he is conscious of Dutch interest in this field, particularly with respect to milking. In fact, there is a dearth of mental work load studies in the analysis of field situations in general.

3.2 Workload in Herringbone Milking

The National Agricultural Advisory Service had expressed concern about the mental strain placed upon milkers in herringbone parlours. It was suggested that this was a prime reason for some milkers leaving herringbone milking. At the same time as studying mental work load, it was considered worthwhile to have an assessment of physical work load. To date results on two milkers have been obtained, although for physical work load heart rate calibrations have not yet been carried out so that results are not known in terms of energy expenditure. Each subject has been studied for three morning and three afternoon milkings. The subjects have been working in ten-stall, five-unit parlours, about seventy cows being milked each session, this taking approximately one hour thirty minutes.

3.2.1 *Mental work load*

A subsidiary task method of assessment was used. A number of mental load programs, recorded on magnetic tape, were used in preliminary studies in bail-type milking parlours. These tasks were based on the detection of:

(i) High tones in a series of low tones;
(ii) Certain tonal sequences among a series of such sequences;
(iii) Certain numerical sequences;
(iv) Changes in numerical sequences;
(v) Sequences of pairs of tones, one tone in a pair changing from the previous pair.

Methods (iii) and (iv) were in the manner of Brown.[47,50] Method (v) was eventually selected, the others being rejected on the grounds of extreme ease, or difficulty, or yielding too little data. Ideally, a secondary task should yield a response per item presentation. An explanation of method (v) will indicate that this was achieved. Suppose the sequence of tonal pairs given in Fig. 1 was presented to the subject:

	Positions 1 2	Response required
Successive pairs of tones	H — L	
	H — H	2
	L — H	1
	L — L	2
	L — H	2

Fig. 1. Representation of the mental load program and responses

The positions in each pair are labelled 1 and 2. In the following pair the tone in one position, but only one, has changed. The response required is the number of the position that has changed. This is not so easy that it can be done almost semi-consciously, but it has not proved too difficult for the subjects who have used it in field situations. Its difficulty is reduced by the use of a strategy which is explained to all subjects to reduce individual variations. By considering only one position in each pair, if that position changes then its number is the response; if it does not change, then it must be the other position.

For some subjects, performance changes with familiarization so that learning time must be allowed for. Guesswork could be a problem, but it is emphasized to the subjects that the basic task is more important, errors being allowed on the mental load task. The use of guesswork would be easily observed in the data.

To facilitate data analysis, the program sequence was printed on sheets, with adjacent columns for the subject's response and task activity. The mental load program lasted eight minutes and this was presented three times during each session. Three afternoon and three morning sessions were studied for each subject.

Results

The coding of responses according to task activity suffers from the usual problem of activity sampling, namely deciding upon the activity at a given time. Despite this, analysis of the task was required at the elemental level. The elements involved are the entry and exit of the cows, for milking, feeding, washing and drying the udders, recording the milk yield, removing and attaching the cluster, machine stripping with the operator's help, and dipping the teats.

The average cycle times (not including exit and entry of the cows) for the basic task with and without the subsidiary task were 9·6 and 10·0 minutes. These indicate that the addition of the subsidiary task did not slow down basic task performance. The slight decrease found when the subsidiary task was added is slightly disturbing; it may not be significant or it may indicate a change in the level of arousal or motivation of the subjects.

The results for the two subjects are presented in Figs. 2 and 3.

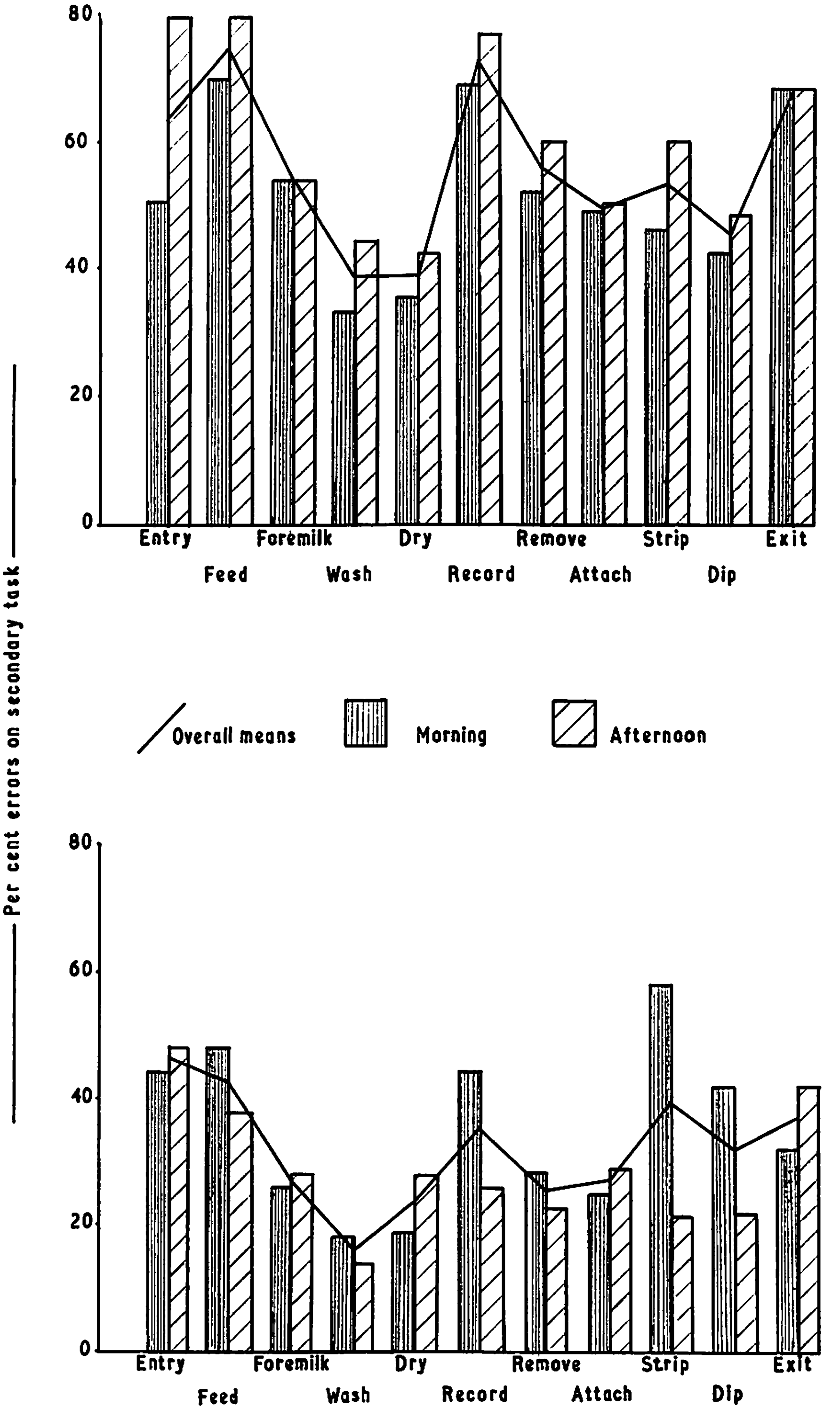
The overall means are drawn as a line graph to facilitate observation of the results; it does not, of course, imply a relationship between the task elements. Peaks in the error distribution curve are apparent for the tasks of entry and exit of the cows, feeding and the recording of yields. Stripping by the operator did not always occur regularly and the peak for subject FL may be spurious due to relatively few observations. The peak levels associated with entry and exit of the cows may also require careful interpretation. Cows do not usually file in or out of the parlour in regimental fashion. The operator often has to prod or shout at them to achieve this. Shouting obviously means that he cannot respond to the subsidiary task and the overall load might be better termed as 'irritation' or 'annoyance' rather than mental load.

The peaks of primary interest, however, are those for feeding and recording. Recording involves looking at the milk level which is clearly indicated by a scale on the storage jar. The milker must keep this level (a 2-digit number) in short-term memory for a second or so, while he looks for the number of the cow and also its colour grouping (not related to the colour code for feeding), and then note the yield in that part of the recording chart defined by the colour grouping and the cow's number. Feeding involves looking at a colour tag on the cow's tail and setting a lever to a point coded by this colour. Decoding of colour into weight of feed is not required. Up to ten colour tags may be in use, though this varies from week to week. The cows enter in batches of five and allocation of feed is carried out for all at or just after entry.

We do not know whether the observed peaks are within the operator's capacity or exceeding it. At the moment, we only have the subjective comments of the two subjects studied; they did not feel mentally overburdened by the milking routine or any part of it. The author, however, knows of another herringbone parlour where 230 cows are milked over a five-hour period. Different operators carry out the morning and afternoon session possibly because they will not put up with the strain involved, although another reason is that the working day then becomes excessively long. Possibly, stress and its effect increase disproportionately with herd size and length of the milking session.

Although mental load peaks have been identified, definitive evidence of their severity is lacking. It is the author's view, at present, that the peak stresses observed do not warrant task redesign at least for smaller herd management.

Thomas[72] notes that the removal of decision making from the task may be detrimental in that it may lead to loss of motivation and to lowered morale. However, some psychologists reason that peak loads should be reduced by redistribution of the offending elements among the work cycle. The logic of this is that an operator may tend to smooth the peaks by extending the time for the activities involved, or by carrying information in short-term memory until a suitable point arises in the cycle (i.e. a trough of mental load) when it can be processed and action taken. Both of these effects may lower efficiency. However, for both feeding and the recording of yields, there is little or no flexibility in terms of task redistribution. The feeding element must be carried out immediately subsequent to the entry of the cows to ensure that the cows finish feeding



Figs. 2 & 3 Secondary task errors for subjects i) PS & ii) FL before the end of the milking cycle. Similarly, recording of yields can only be done when the cow has been milked, and when this happens the milking cluster and the milk storage jar are required for milking a cow on the opposite side of the parlour. Thus, the smoothing of peaks would appear to require the reduction of the load for the task element in question. The task element of feeding and recording do not appear to have intrinsic or unnecessary difficulties. For feeding, the stimulus (looking at the colour tag) and the response (setting the lever to a point defined by the colour code) are as compatible as could be. Recording involves rather more short term memory capability and, since the subsidiary task was a short term memory task, this may be one reason for the pronounced peak for this element.

Reductions in mental work load may be achieved by simple ergonomics improvements, e.g. for feeding could the colour tags be placed more optimally or made larger? For recording, could the scale design be improved or the identification of the cow? The subjects were questioned on these points, but their comments did not appear to indicate major limitations. An initial consideration of these aspects indicated that there were not inherent limitations that could be easily improved.

Substantial reduction of the peak loads may require partial automation. Before this step can be justified, however, much more substantial evidence is required particularly for larger herd management.

3.2.2 *Physical work load*

The respirometer could not be used in herringbone parlours without the risk of breakage of the storage jars or, alternatively, requiring the operator to move so warily that the nature of the task would be changed. Heart rate measurements were therefore taken. The technique involves a biological amplifier and a telemetry transmitter, both of which were carried by the subject, and a telemetry receiver and tape-recorder in a convenient alcove in the milking parlour. The recordings were analysed manually with a hand-counter and stop-watch, sampling intervals of 30 seconds being used.

The breakdown of the task into elements, as used in the assessment of mental work load, could not be used in the case of physical work load because the elements are too short in length. Valid heart rate measures would not be obtained because of lags in heart rate response. Three conditions were therefore studied; the milking routine itself, the entry and exit of the cows, and the washing down and cleaning of the parlour. The last element could be measured only once per milking session, but the other two were studied on three separate occasions for each session.

Results

The changes in heart rate for the different elements are shown in Fig. 4.

It can be seen that slight increases occur for the exit and entry element relative to the milking routine. How much of this is due to an increase in physical work or to the 'annoyance' component mentioned earlier, cannot be stated. In any case the peaks are not marked enough to be considered as a temporary overload. Washing down, a process taking approximately fifteen to thirty minutes, is also associated with a higher level of work than the milking routine, but again this does not appear excessive.

Although results for more subjects are necessary before absolute conclusions can be made, the results for the two subjects studied suggest that physical work load is not a problem in herringbone milking, i.e. other tasks of the milker are likely to be physically more demanding and more worthy of attention. One subject commented that more strenuous effort was involved in fetching the cows from the

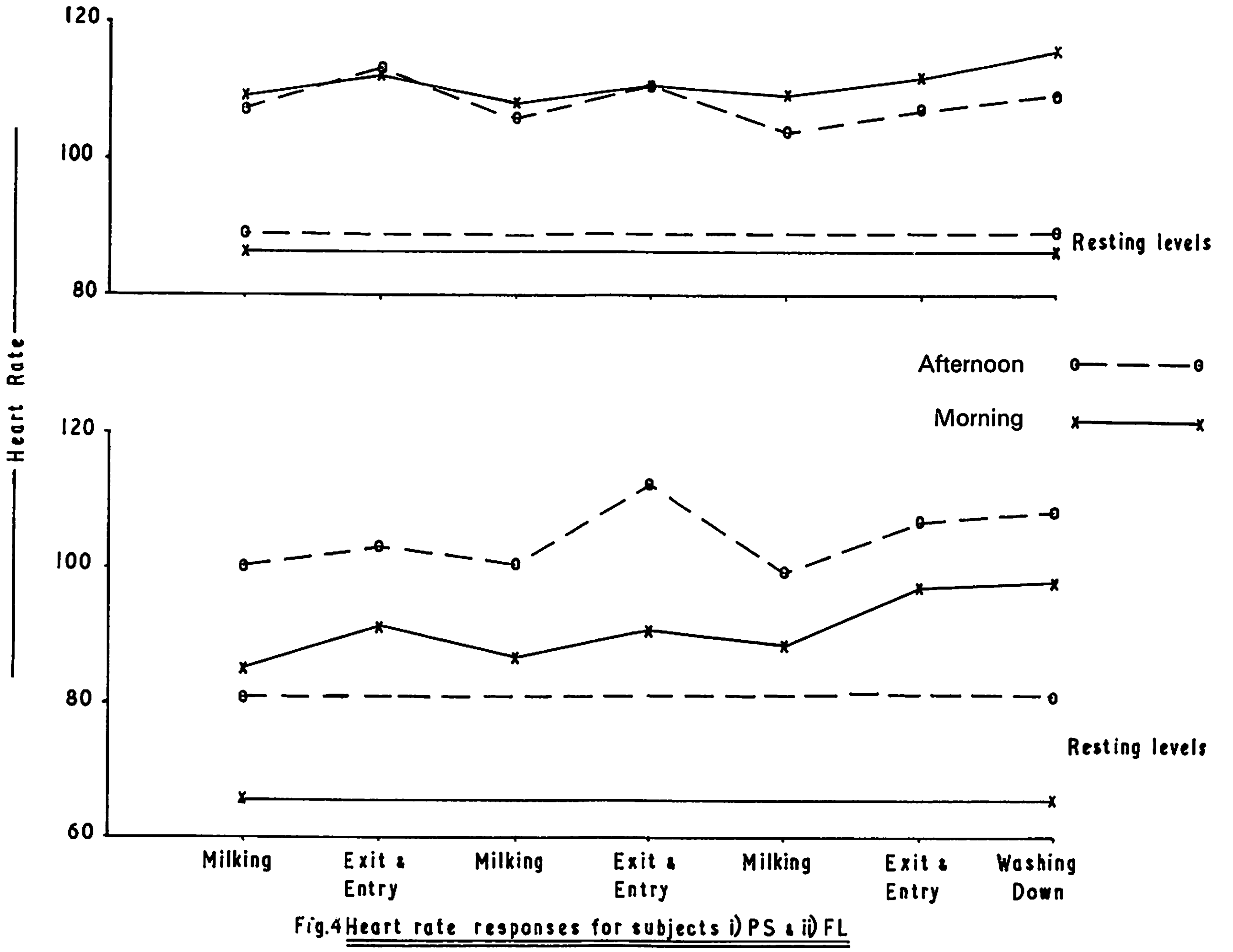


Fig.4 Heart rate responses for subjects i) PS & ii) FL

manger to the parlour than in milking itself. Using Christensen's[2] classification, given in the introduction to this paper, the heart rate results suggest that the overall milking task is a moderately heavy level of work. Vos,[67] in his study of milking, came to a similar conclusion. Likewise, Roberts[73] concluded that, 'In terms of energy expenditure, milking cannot be classed as heavy work'.

Comparisons of workload for different types of loader

The physical and mental components involved in the operation of seven tractor-loader combinations were studied. Three slew loaders, three fore loaders and one rear loader were included in the comparison, the aim of the study being to determine if any one class of loader had consistent benefits, including ease of operation, in relation to the others. Loading of both sand and manure on to a trailer were included using heart rate and respirometry in the assessment of physical workload and a subsidiary task for mental workload assessment. The weight of material loaded per minute was determined at the same time to define rate of work achieved by the loader system.

Experimental design

Three experienced subjects took part. The twenty-one combinations of loader and driver were carried out in randomized order for each type of load, i.e. sand or manure. The type of load was not included in the randomization since different experimental sites were involved. At each point in the randomized order, four experimental runs lasting 3 to 7 minutes were conducted, separate pairs of runs being used for physical and mental measurements.

Physical workload

After the subject had rested for several minutes, heart rate and respirometry measurements were obtained during the same experimental runs. A large enough sample of expired air could not be collected in one experimental run so that a respirometry measurement was taken over each pair of runs. Heart rate, however, was recorded for separate runs. The respirometry measurements include the basal metabolic rate.

Results

Significant differences between loaders for both types of load were obtained for both measures except in the case of heart rate for loading manure (Tables 2 to 5). The results are presented graphically in Figs. 5 and 6. In all cases the slew loaders required the least physical effort, with little difference between the fore loaders and the rear loader. The results are even more marked if the ratios of the energy expended per minute to the weight loaded per minute are used (Fig. 7). This measure also shows that, for the loading of manure at least, rear loading is by far the most inferior method in terms of energy cost. This is presumably because the loading of manure requires more skill in its handling and when operating a rear loader the operator is not optically placed to view the task so that the work rate is decreased. Further, it can be seen that the loading of manure requires more energy per unit loaded than the loading of sand, although the energy expenditures per minute (Fig. 6) are roughly the same, since the loading of manure is a much slower process.

The overall levels of energy expenditure (Fig. 6) are worthy of note. The effort in operating slew loaders appears acceptable, but for the other loaders the levels are above or near to the acceptable level of 5K cal/min proposed by Lehmann.[1] Further, Lehmann's proposed standard applies to the normal working day of eight hours. In agricultural work, however, the working day may be well in excess of this, so that it can be concluded that the fore loaders and rear loader studied would require a level of effort above the acceptable standard if work was continuous for such a day.

Mental workload

The subsidiary task was the same as that used in the milking parlour study. The subjects performed the mental load program several times prior to the experiment to familiarize them with the procedure and to reduce the effects of learning. The program was relayed to them via headphones, the loudness being adjusted to a comfortable level, and the program and their responses were recorded simultaneously on a tape recorder for subsequent analysis.

Results

The results are presented in Fig. 8. The differential levels of error between the loaders were not consistent for sand and manure loading. This is thought to be due to large within-individual variations, i.e. additional replications would be needed to produce meaningful mean levels of error. Consistent differences between the loading of sand and the loading of manure were not apparent and since marked differences in rate of work were found between loaders and also between loading sand and loading manure, the percentage errors were recalculated in a form corrected

TABLE 2

Analysis of variance for energy expenditures in the loading of sand

Source	s.s.	d.f.	m.s.s.	F-ratio
Subjects	0·4	2	0·2	N.S.
Loaders	19·6	6	3·3	5·45 sign at 0·01
Subjects × loaders	7·2	12	0·6	
TOTAL	27·2	20		

TABLE 3

Analysis of variance for energy expenditures in the loading of manure

Source	s.s.	d.f.	m.s.s.	F-ratio
Subjects	0·2	2	0·1	N.S.
Loaders	27·1	6	4·5	24·38 sign at 0·001
Subjects × loaders	2·2	12	0·2	
TOTAL	29·4	20		

TABLE 4

Analysis of variance for heart rates in the loading of sand

Source	s.s.	d.f.	m.s.s.	F-ratio
Subjects	11,238	2	5619	28·50 sign at 0·001
Loaders	4,868	6	8113	4·1 sign at 0·025
Subjects × loaders	2,370	12	198	9·3 sign at 0·001
Samples	445	21	21	
TOTAL	18,921	41		

TABLE 5

Analysis of variance for heart rates in the loading of manure

Source	s.s.	d.f.	m.s.s.	F-ratio
Subjects	5597	2	2798	11·6 sign at 0·01
Loaders	3368	6	561	2·3 N.S.
Subjects × loaders	2907	12	242	15·1 sign at 0·001
Samples	336	21	16	
TOTAL	12,208	41		

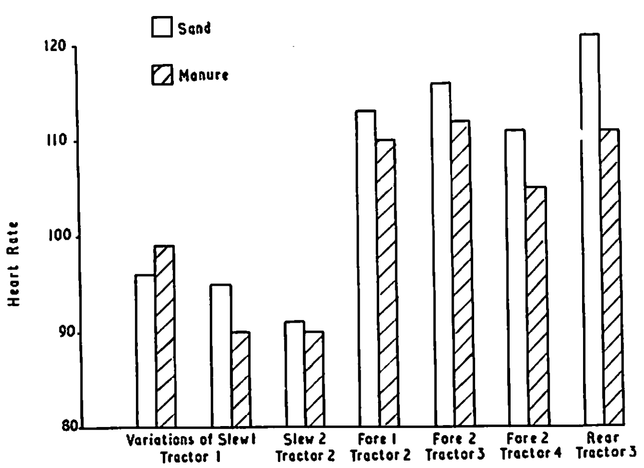


Fig. 5 Heart rate responses vs. loader type

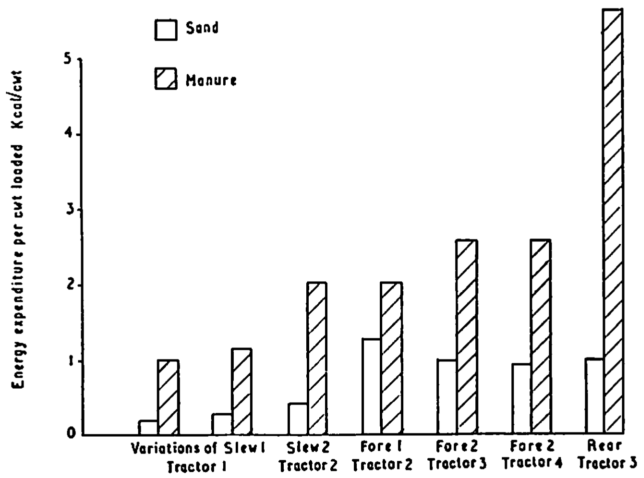


Fig. 7 Energy cost per unit of weight loaded

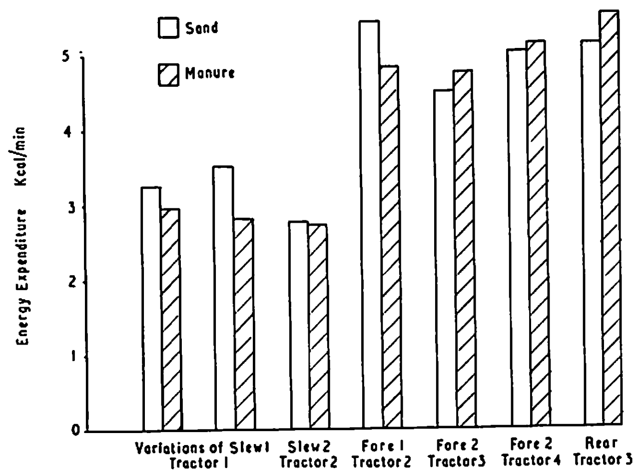


Fig. 6 Variations in energy expenditure for the differing task conditions

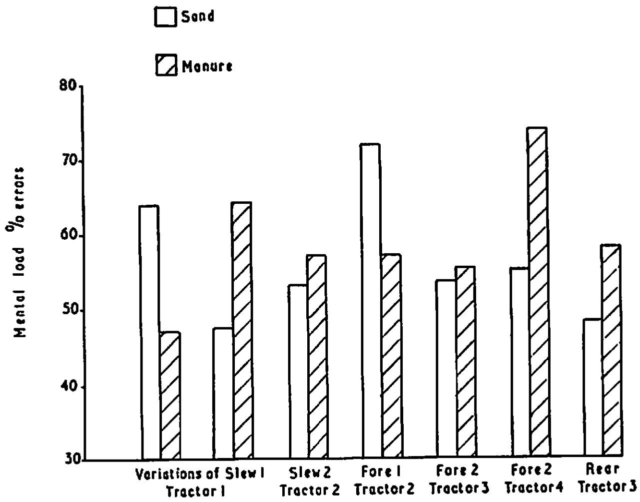


Fig. 8 Errors on the subsidiary task

for rate of work, i.e. the errors were divided by the unit loading time. The corrected error levels are shown in Fig. 9. It can be seen that, relative to the unit load, the loading of manure demands more mental effort than the loading of sand. Since the uncorrected errors for the two types of load did not appear markedly different, it can be concluded that the slower rate of work for manure loading permits a greater degree of time-sharing between the loading task and the subsidiary task so cancelling the greater mental effort per unit of load.

Meaningful conclusions probably cannot be drawn for the types of loader from the errors corrected for rate of work because of within-individual variations. The large differences between rates of work in sand and in manure suggest that the nature of the task may be very different for the two cases; hence it would probably be inappropriate to sum the results for the two tasks for each loader.

To check whether the application of the subsidiary task reduced the speed of work, the loads per minute during physical measurements were plotted against the corresponding loads obtained during mental measurements (Fig. 10). All subjects and all loaders are represented. A preponderance of points above the theoretical diagonal would indicate that the subsidiary task slowed down the rate of work. This did not occur except where very fast rates of work were obtained during physical measurements, i.e. for the slew loaders in sand. If the results discussed above had permitted comparison between loaders, conclusions concerning the use of slew loaders in sand would have been placed in some doubt since the check graph suggests that in these cases the subjects slowed their rate of work in achieving their level of performance on the subsidiary task.

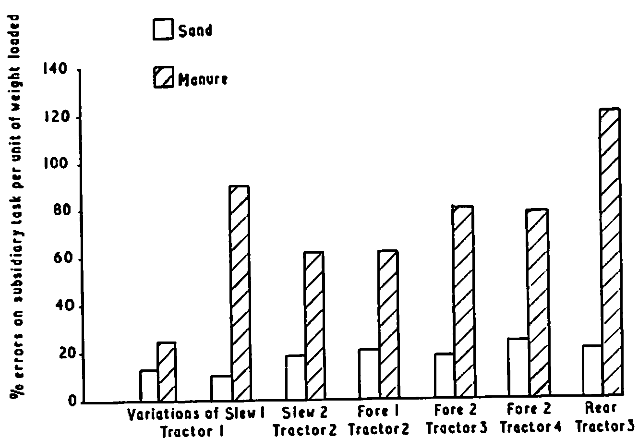


Fig. 9 Errors in the subsidiary task corrected for speed of work

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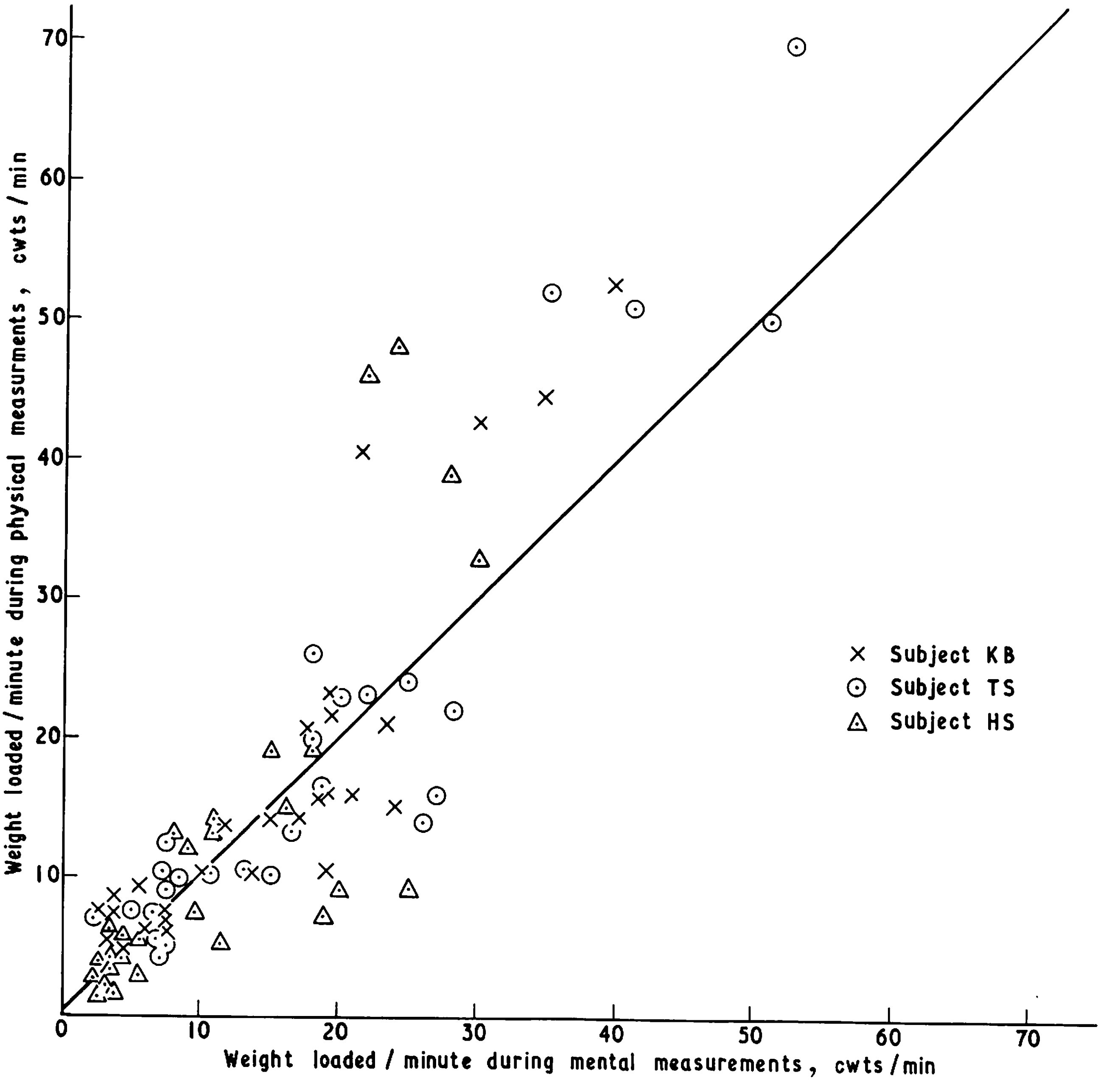

Fig. 10

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Ergonomics in agriculture

STUDIES OF COMBINE HARVESTER OPERATION

by J. ZANDER*

Presented at the Autumn National Meeting of the Institution at Loughborough University of Technology on 4 September 1969

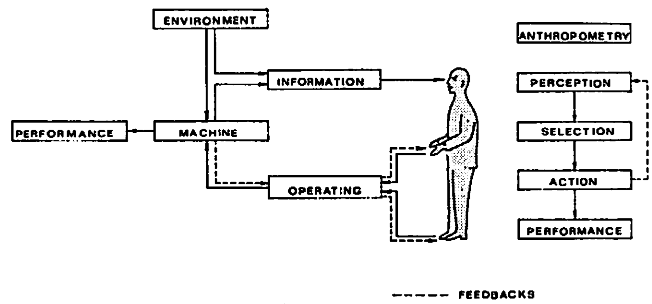

Fig. 1. A man-machine system.

1. Introduction

1.1 General

In the framework of modern economics, agriculture cannot possibly work without rationalization and mechanization, which replace human labour by machines and contribute to raise productivity. An important part in this process is the increasing desire for making the job easier and shortening the working hours.

The need for higher output leads to working at higher speeds in grain harvesting operations, in which bigger and heavier combine harvesters are also used. It is not possible and should not be necessary for man to be able to continue adapting himself to his task indefinitely. For this reason 'ergonomics' or 'human engineering' should be considered as a fundamental subject and an essential part in the engineering design of farm machinery, to fit the agricultural job to the agricultural worker.

1.2 Description of an Ergonomic Model

The multi-disciplinary approach of ergonomics can be illustrated by the different processes (see Figure 1), representing a man-machine system .[17]

A continual stream of information is received from the machine and the environment by the working man using his senses. This process is called *perception*; it constitutes the perceptual load on the man. Perception is followed by testing against the memory, and then making decisions between alternatives to select a specific operation. This process is called *selection*; it leads to the mental load on the man. The output of the man consists of voluntary muscle movements, which are necessary for the operation. This process is called *action*; it leads to the physical load of the man.

Through the action a change takes place in the man-machine system; it results in a *performance.*

Finally the man observes the effect of his actions, revises his decisions and takes new actions to bring the system closer to its goal; this process is called *feedback.*

Moreover a man must spatially fit in the system; the discipline, which takes care of these aspects of the human body, is called *anthropometry.*

Many factors can influence the effectiveness with which a man performs his task and the output of the system. Among these are the design of the instruments displays, and the design of the controls, which he operates through his voluntary muscle system. Another factor is the environment in which a man works; acoustic and mechanical vibrations, dust, cramped body positions all act to degrade his performance.

An ergonomic analysis must lead to the design of a non-stop man-machine system with a high performance capacity and a reasonable load for the man.

2. Scope of the Study

Governed by the condition of the crop and the condition of the terrain, the driver of a self propelled combine harvester controls from the operator's platform the forward movement—in direction and speed, the cutting and the threshing mechanisms, the separation of grain and straw and transport of the products.

Based upon the information received, the driver has to decide on the adjustment of the machine in such a way that a continuous process with a high capacity will be the result.

The purpose of the summarized research project was to study and analyze the factors which—directly or indirectly—influence the operating of a self propelled combine harvester.

The research consists of the following items[18]:

1. Collection of data about the character and the extent of the work load components in the system (lay-out studies).
2. Studying and analyzing these components and their influences and effects, by means of indoor and/or outdoor experiments (field and indoor experiments).
3. Designing and formulating the procedure, with necessary criteria, for the design of an optimum man-machine system.

3. Lay-out Studies

Because of the design and evaluation of man-machine systems we ought to take into account the anthropometric aspects of the human body, as well as the frequency of the actions.

Through statistical research carried out on behalf of the ready-made clothing industry and of the army, knowledge of these aspects on large population groups has been considerably extended during the last several years. In particular regarding body measurements, body movements and manual or pedal forces which can be applied have been reported.[5,6,10,13,16]

The results of the workplace lay-out studies, for which special measuring equipment has been developed,[17] lead to some interesting conclusions.

(*a*) *Controls*

Controls, used frequently (particularly: steering wheel, header height control (M_b), reel lift control (M_h) and ground speed control (M_v)), on most combine harvesters have been placed within or at the limit of the optimum area for the man;

Other controls are often found far beyond these areas;
The figures about the location of the controls appear to differ considerably for a number of combine harvesters;

To reduce the possibility of operator confusion the provision of recommendations for the standardization of location and direction of controls is necessary (Figure 2).

(*b*) *Forces*

The forces needed for operating the footbrake and the clutch pedal are high (25-28 KG); these forces differ only slightly or not at all for most combine harvesters;

The forces needed for steering are low (< 6 KG)—mainly because of the application of power steering. □

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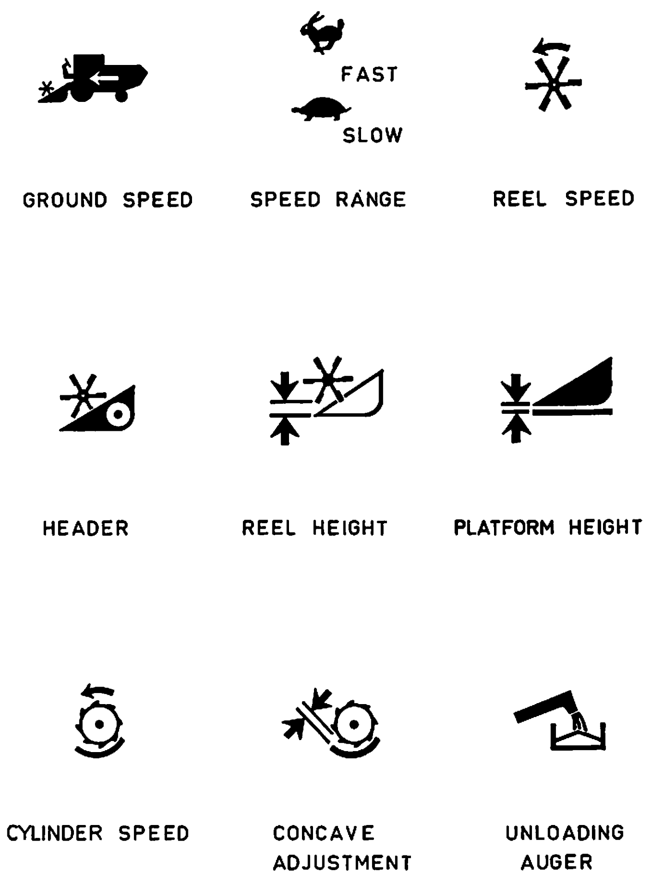

Fig. 2. Universal symbols for the controls of a combine harvester.

The load on a man not only depends on the body measurements, the movements and the forces, but also on the frequency and the sequence in which the various operations have to be carried out. Controls which are most frequently operated need to be installed, as far as positions and displacements are concerned, within the optimal areas, as already indicated.

The results of the research include the following points: Of all controls, the header height control (M_b), the reel lift control (M_h) and the ground speed control (M_v) are the most important ones (M_b, M_h, M_b—74·8%, 12·8%, 12·4% respectively);

The position and the displacement of these controls—and the position of the steering wheel—deserve priority when arranging an operator's platform;

The movements of the steering wheel only have a correcting character, at least at the straight parts of the plots. The results are shown in Table 1.

TABLE 1

Steering wheel movements of combine harvesters

Turnings	Percentages
0 –1/6	37·0
1/6–2/6	34·7
2/6–3/6	19·3
> 3/6	9·0

(*c*) *Movements*

By means of MTM (Method-Time-Measurement) and in combination with the frequency of operation of the various controls, we can obtain an impression of the ergonomic quality of the layout of a certain machine.

For the time calculation, based on 100 control operations we use—based upon the results of field surveys of operations—a ratio for frequency between the most important controls (M_b, M_h, and M_v) of 75·0%, 12·5% and 12·5% respectively.

The results of these analyses are shown in Table 2.

TABLE 2

Results of MTM-analysis

(Dimensions: Time Measurement Units)

	M_b	M_h	M_v	Total	75·0–12·5–12·5
Machine 1	18·0	36·8	43·4	98·2	2352·50 (4)
Machine 2 type: A	21·2	41·8	45·8	108·8	2685·00 (5)
Machine 2 type: B	12·3	33·1	31·3	76·7	1727·50 (2)
Machine 3	10·2	29·2	52·8	92·2	1790·00 (3)
Machine 4	8·2	28·4	29·2	65·8	1335·00 (1)

M_b—Header height control;
M_h—Reel lift control;
M_v—Ground speed control.

Even at a superficial observation of these data we already notice that:

At the accepted division of the operation frequency the required time for the header height control (M_b) becomes relatively more important;

A small modification in the lay-out of the operator's platform (see Machine 2, type A and B) might lead to a favourable change in the effective operating time;

A development in the direction of the 'fingertip control' (Machine 4: Massey-Ferguson) might open favourable perspectives—anyway based upon the movements to be made and the forces to be applied.

With the antropometric data we can contribute to a considerable decrease of the work load; in my opinion this could lead—in a rapid and simple way—to an improvement in performance too.

4. Field Experiments

The output of a man-machine system is mainly determined by a number of factors, which directly (primary) and indirectly (secondary) are of influence.

For instance the capacity of a combine harvester can be enlarged by increasing the ground speed and/or the working width, which, however, involves a higher information speed, more actions for operating and a higher work load of the operator. Through estimations in practice the information speeds have become known.[14]

TABLE 3

Information speeds of combine harvesters (in bits/second)

Primary information:	
Terrain	2 bits/second
Crop	9 bits/second
Working width	2 bits/second
Secondary information:	
Threshing quality	4 bits/second
Noise	2 bits/second

From qualitative published information we might conclude that the operator's control task on a combine harvester probably is the most taxing of all in work with agricultural machinery; although the physical load of the operator might be described as from light to medium-heavy.

4.1 Direct Influences

Although the combine harvester is a very old machine, in the literature very little has been reported about the ergonomic aspects; it is possible to indicate a number of factors, which influence the output of the machine and the load on the operator.

In recent years we have investigated the factors, which directly influence the work load of the operator:

Operator's platform (M)
Stubble-height (S)
Ground speed (V)
Working width (W)
Header height control (H)

In studying the above mentioned effects the following phenomena have been used:

(*a*) Operation frequency.
(*b*) Heart rate.

During the experiments the stubble-height, the ground speed and the effective working width were checked regularly, in order to establish whether the quality of the work met with the requirements.
Some results were:

4.1.1 *Operator's platform (M)*
The lay-out of an operator's platform is specific for a certain make and/or type of combine harvester;
Each operator's platform produces its own level of load, which is measurable;
The differences between machines become greater when working at higher ground speeds.

4.1.2 *Stubble-height (S)*
There appears to be a significant difference between various stubble-heights;
Increased stubble-height decreases the load of the operator.

4.1.3. *Ground speed (V)*
The effect of ground speed clearly exists;
This effect increases as speed increases;
This effect is different for each machine.

4.1.4 *Working width (W)*
Both in summer barley and winter wheat we found a significant effect of the working width;
Operators mostly prefer a particular working width.

4.1.5 *Header height control (H)*
It is shown already from the layout studies, that the header height control is the most frequently operated control;
I have already reported that using an automatic header height control gives a decrease in load;[18]
The effect of the automatic header height control increases with higher ground speeds;
The operator has to be automation-minded too.

4.1.6 *General*
The interaction between speed and width, affecting output, clearly exists;
To obtain a certain capacity there is an advantage in adopting greater working width and lower ground speed.

4.2 Indirect Influences

In the preceding paragraphs it has already been stated that many factors can affect the effectiveness with which a man performs his task. In this particular group of exogenous factors the issue at stake is the loads and stresses which are necessary for the output; the human body can resist certain factors—like climate—but not factors like noise, mechanical vibrations, dust, chemicals, etc.

4.2.1 *Acoustic vibrations*
Much is known about the impairment of hearing created by noise, but there is no direct information on the effect of noise on operator's efficiency. In general noise has been shown to affect the efficiency of the worker on a job demanding careful attention. Investigations indicated that sound levels above Noise Rating Number 85—depending on the duration of the exposure—were considered to be excessive.

Some results:
The noise produced by self-propelled combine harvesters—measured at ear height—is too much (measured levels: 90 ± 3 dB);

The existence of a cab on the machine does not lead to a decrease of the sound pressure level.

4.2.2 *Mechanical vibrations*
Operators of farm machinery as well as of various other types of off-the-road vehicles are subjected to mechanical vibrations which adversely affect their health and performance. Most of these vibrations arise either from imbalances or uncompensated accelerations in the machine itself or from irregularities in the field.

In recent years we have given attention to the intensity of the apparent mechanical vibrations experienced—in the horizontal and vertical directions—and their frequency distribution, on a number of combine harvesters.

Some results:
The intensity of the measured vibration is small;
With increasing ground speeds there appears—at least when harvesting—to be no difference in intensity;
The frequency distribution indicates the existence of specific frequency components (4–6 cycles/sec), which are characteristic of the machine;
It is not essential, in the author's view, to provide the grain combine with a suspension seat.

4.2.3 *Dust*
Although little work appears to have been reported on the composition of dust and its possible effect on health, measurements have been made of dust concentrations on combines, with levels in the range of 0·2–0·6 mg per cubic foot of air.

Results of our dust measurements include:
On a combine harvester without a cab the dust concentration of the air around the operator is considerably higher than on a combine harvester with a cab:
(without cab: 4·2 mg per cubic foot of air)
(with cab: 0·3 mg per cubic foot of air);
There is a remarkable difference in percentage of quartz in measuring the kinds of dust obtained:
(combine harvester without cab: 2·37%)
(combine harvester with cab: 9·67%);
Examined in the same crops we determined differences of 30–40% in dust concentrations between the various machines.

5. Indoor Experiments

5.1 Introduction

For studying and analyzing the loading components of a man-machine system under controlled conditions, a simulator has been built. This makes it possible to obtain information regarding the ergonomic qualities of an operator's platform of a particular combine harvester, as well as of the consequences of modifications, if any, in the layout of the platform, within a relatively short time. Naturally a simulator offers possibilities for further experiments, such as the training effect or habituation to a particular machine.

5.2 Parameters

Even more than with the field experiments, the emphasis of the indoor experiments is placed upon the mental load of the working man. In addition, we tried to develop adequate parameters, which also have to be applicable to investigations outside the laboratory.

To assess the mental load of a working man we can use the following methods:

5.2.1 *Measurement of performance of the task*
In view of the performance of the task—qualitatively: number of misses, mistakes and errors; quantitatively: time per unit of task, task per unit of time—the load might be assessed.

5.2.2 *Psychological measurements*
The method of the 'subsidiary task' or 'performance under experimental distraction' has been adapted in the research on the metal load; during the performance of the task is added a second task, which is variable both qualitatively and quantitatively. A number of experiments has been reported in literature on this method, in which the mutual effect of the main task and the subsidiary task is being traced. [3,8,9,11,12]

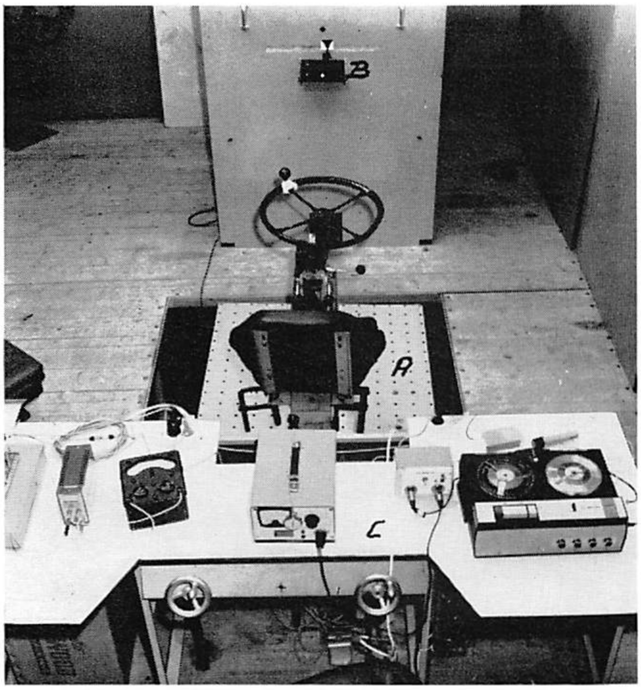

Fig. 3. The simulator for man-machine systems. (A: Platform; B: Instruction; C: Scoring).

The main task is a simple, repetitive one, which must be looked upon as the principal task under all circumstances.

Against this, the subsidiary task must be performed as well as possible.

5.2.3 *Physiological measurements*
Physiological parameters are applicable to describing the mental load of a task.[1,2,7] Summarizing, we can say that the mental load can be associated with:

1. An increase of the heart rate;
2. A decrease of the sinus-a-rhythmia of the heart rate;
3. An increase of the blood pressure;
4. An increase of the respiration rate;
5. An increase of the oxygen consumption.

For the assessment of the mental load the 'subsidiary task' (5.2.2) and the heart rate (5.2.3.1 and 5.2.3.2) have been selected as most suitable.

5.3 Simulator

The simulator consists (Figure 3) of:

5.3.1 *Platform (A)*
On the platform—the upper side of a vibration table—the operator's platform of a combine harvester can be installed; the relative positions can be varied, whilst different types of controls can be attached.

5.3.2 *Instruction (B)*
The experiments are carried out with a simple repetitive main task, which has to be carried out without faults.

For that purpose the testee has to react to light signals, corresponding with the position which can be taken by header height control (M_b), the reel height control (M_h) and the ground speed control (M_v).

The sequence and the frequency of the signals have been sent from a punched tape, of which the speed is adjustable; the distribution for the different controls is according to the MTM-analysis.

For the 'subsidiary task' use is made of the compensatory tracking ability.

5.3.3 *Scoring (C)*
As well as the subjective responses of the people under test the heart rate and the steering accuracy are recorded.

It appears that—under the influence of the experimental distraction—the performance declines, whilst the load of the working man increases, as shown in Figures 4 and 5.

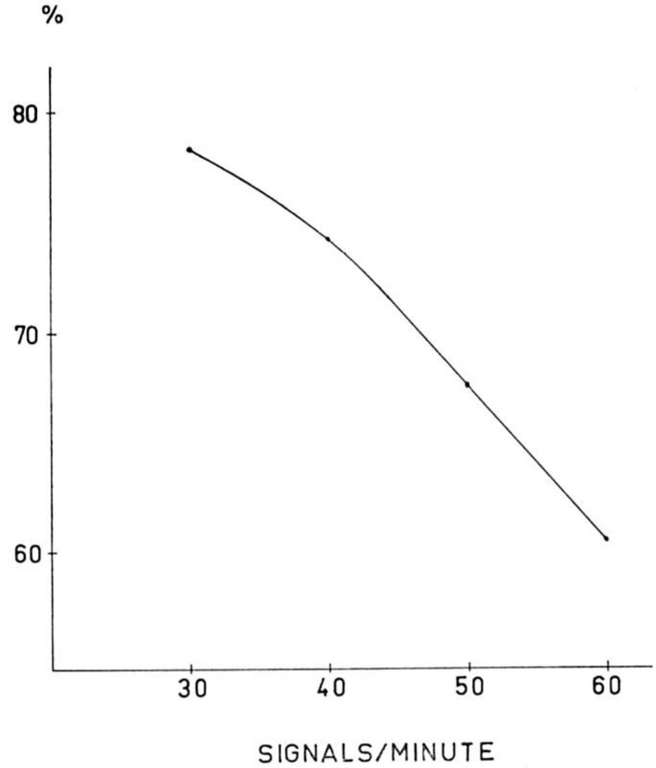

Fig. 4. The steering accuracy (in %)—performance under experimental distraction—in simulated operating of combine harvesters.

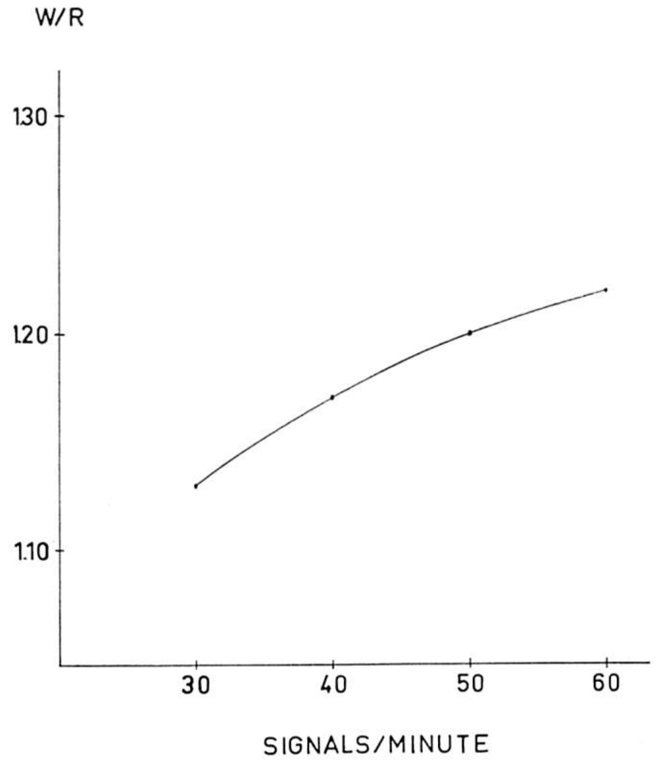

Fig. 5. The work load (W/R)—performance under experimental distraction—in simulated operating of combine harvesters. (W: Heart rate during testing; R: Heart rate during resting).

5.4 Experiments

In recent years the ergonomic qualities of different combine harvesters have been assessed; the test subjects, after a period of rest, were offered test conditions with 30, 40, 50 and 60 signals per minute (= 1·58, 2·00, 2·30 and 2·58 bits/second respectively), in sequence.

Some results:
Increasing the number of signals per minute, the steering accuracy decreases and the load increases;
There appears to be a significant difference between the various machines, which becomes more significant as the external load increases (Figure 6);
(This effect conforms to the ground speed effect of the field experiments);
Habituation differs with the various machines.

It is known that—when repeating a task—a change occurs in the time needed per cycle and in the load; when increasing the number of cycles the time needed decreases—at first fairly quickly—to become almost constant subsequently.

With the load on the man an analogous situation develops; when repeated many times, the load increases.

We also investigated on two machines whether the presentation of different series of signals (30–50–0–30–40–50 per minute and 50–30–50–40–30–0 per minute) influenced the learning process.

As could be expected in view of the information found in literature,[4,15] variations in tasks do influence the effect of learning.

Furthermore, we checked whether the length of a test run, in particular the repetition of the task, influenced the effect of learning on two different machines.

Some results:
When presenting identical series of signals (40 signals per minute), interrupted by short periods of rest, we clearly find learning, based on the steering accuracy as well as on the heart rate;

Between two different machines a difference in familiarization does exist.

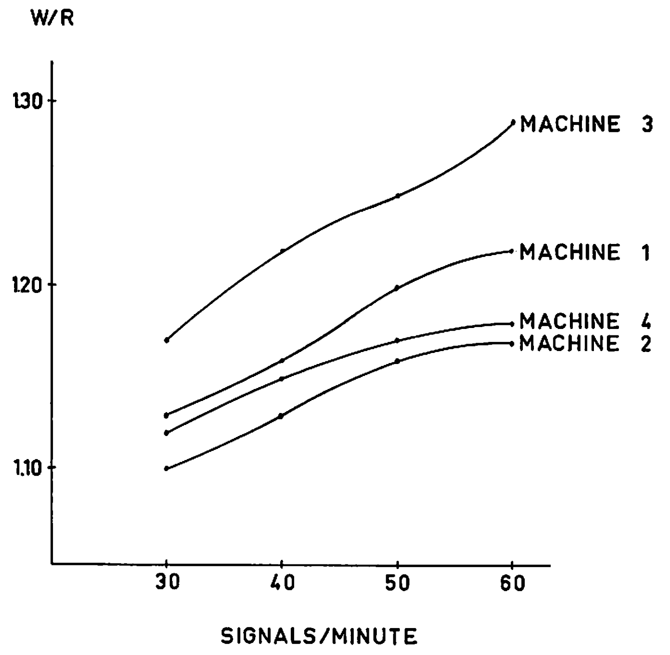

Fig. 6. The work load (in W/R) in simulated operating of different combine harvesters.

6. Summary

The need for higher performances leads to working with higher speeds and bigger combine harvesters. It is neither likely nor necessary that man can adapt himself to his task indefinitely.

In spite of the technical possibilities of automation of a combine harvester, it has become evident that 'ergonomics' must play an important role in the improvement of the conditions of work, to optimize the efficiency of the operator's task.

The co-operation of man and machine in a system can be illustrated by a model, in which all processes—in particular perception, selection and action—and their feedbacks, determine the output or performance of the system.

Moreover, the environmental and the anthropometric factors can affect the effectiveness of the system and degrade the performance.

The purpose of this study of combine harvester operation was to study and analyze the loading components in this man-machine system, aiming at providing information based upon the results obtained, to improve the operator's platform. The research consisted of the following items:

6.1 Layout Studies

The workplace layouts appear to differ considerably for a number of combine harvesters.

Assuming that the layout of an operator's platform is specific for a certain make and/or type of combine harvester, already we can with the available anthropometric data—in a rapid and simple way—contribute to important improvements and, indirectly, to a decrease of the work load.

6.2 Field Experiments

The output of a combine harvester is determined by a number of factors, which directly and indirectly are of influence in the rate of work.

Using the operation frequency and the heart rate as parameters, the character and the extent of the loading components in the system—particularly: the operator's platform (M), the ground speed (V), the working width (W), the stubble-height (S) and the automatic header height control (H)—have been investigated. Among others there clearly appears to exist the interaction between speed and working width (V × W), representing output, whilst—to obtain a certain capacity—there is a definite tendency to operate with greater working width and lower ground speed.

Attention was also given to the character and the extent of the indirect factors, in particular noise, mechanical vibrations and dust.

6.3 Indoor Experiments

For studying and analyzing the loading components under controlled conditions a simulator was built; this makes it possible to gain, in a relatively short time, an impression regarding the ergonomic qualities of a certain operator's platform, as well as of the consequences of modifications in the layout.

Thus we found for instance that whilst performing the simulated operating task—influenced by experimental distraction—the performance of a task clearly decreases, whilst the load of the working man increases. This effect is different for each machine and correlates with the effect of the ground speed, which we established in the field experiments.

A difference in training time requirement also exists, between the machines which is of importance when judging the ergonomic qualities of a certain operator's platform.

The human factors—especially the application of ergonomics in agricultural engineering—not only deserve full attention, but are decisive in the question of whether or not the farmer will have a reasonable living in the future, comparable with other professions.

In my opinion this is reason enough for working at full speed to obtain the necessary data for the design of farm machinery, in order to obtain man-machine systems with a high capacity and a favourable load for the worker in agriculture in the near future.

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Ergonomics in agriculture

DISCUSSION (First Session)

Chairman: C. CULPIN, OBE, MA, DIP AGRIC, FI AGR E *

Presented at the Autumn National Meeting of the Institution at Loughborough University of Technology on 4 September 1969

MR D. EVANS (Agricultural, Horticultural and Forestry Industry Training Board) asked if herringbone milking parlour operators who had been studied had been initially confronted with the full working situation or whether any attempt had been made to draft them gradually into the working system. The stress encountered from sudden confrontation might indicate the need for stamina build-up so that people were drafted gradually into the working system. Thus, parts of the job would be tackled almost automatically before operators went on to study the next part. Mr Evans also enquired whether there was any indication that stress fell off after a month or two of working with the system; it could be that having got used to the working of the system the stress factor diminished.

DR R. W. TOMLINSON (NIAE) replied that the two parlour operators studied had both been experienced milkers; inexperienced subjects had not been used. Consequently, the effect of stress could be assumed to have settled down to a fairly constant level by the time they were studied. Familiarity with the subsidiary task was in this case of greater importance as there was obviously a lot of learning attached to it and there had then to be repeated exposure to the task before actual measurements were taken.

Measurements had not been carried out to establish whether the stress on a milker was reduced with familiarity with the milking task itself. This was one aspect that the secondary task could be used for, as it could in a study of 'fatigue'. The subsidiary task was in general useful for studying learning habituation to a work situation.

MISS S. H. READ (Dairy Husbandry Specialist, NAAS) enquired if there was any optimum number of tasks which might be brought into one job, below which the operator might experience such a degree of tedium that any kind of interruption could upset the routine; equally, whether there might be so many distractions *above* the optimum task that continuation of the routine would be upset.

Dr Tomlinson thought that one could not describe or define an optimum number of basic elements within a task. It would depend on each specific situation. One ought really to talk of the amount of information processing required by a particular task. The amount of mental work in a task could probably be reduced and it was his own view that one could reduce this to the level where it became so boring that performance deteriorated. This was a controversial point because there were those who believed that peak-loads should be reduced, whatever the circumstances.

Mr Evans said that if one could define an optimum level for mental work it would be interesting to know if there was not also a low limiting level. In terms of a vibrating tractor seat, he did not visualize the day when a tractor driver would go home feeling the need to take further exercise, but there might be a lower level which was desirable. Mr Evans further enquired if the tractors in the loading experiment, particularly the front-loaders, had been fitted with power steering.

Replying to the question about the lower level of physical work-load, Dr Tomlinson said that there was obviously a circular pattern in that the less work one did the less work one was capable of, but he thought the levels being considered here were above any minimum level one might care to consider. In practice, the question might not arise because it was to be assumed that farmers were aware of the faster rate of working of which slew loaders were capable. If a farmer had a good deal of loading to do, he might well consider it worthwhile to go to the greater expense of buying a slew loader. On the other hand, if he had less loading to do, he might go for a front loader on grounds of cost. In these cases, although one referred to a maximum level of 5 k/cal per minute, strictly speaking this was only advocated as an average measured over several weeks at least. If one was really thinking in terms of several days rather than weeks or months, and if the worker had only a small amount of loading to do, then peaks greater than 5 k/cal per minute could not be objected to.

In reply to the point about power steering, Dr Tomlinson said that this had not been incorporated in the fore-loaders and he agreed that this had been the main reason for the increase in effort. Not only did the loader have to be moved but the tractor as well and the steering force was therefore probably the main reason for the much higher level in those cases.

MR. J. MATTHEWS (NIAE) touched on a problem mentioned by Dr Tomlinson of the effect of the increasing herd sizes on the manning of milking parlours. Could Dr Tomlinson say why he had started with small numbers of cows, when really the problem was with large herds and could he perhaps explain where this might cause the ergonomics investigation to be directed?

*President-Elect, The Institution of Agricultural Engineers

Dr Tomlinson said that small numbers had been decided upon in the first instance in the context of a study at NIRD at Reading, having regard to the early stage of technical development at that juncture. Obviously there was more interest in larger herd management and they had wanted to get any 'teething problems' out of the way before going on to that stage. They had been interested in the whole scheme of milking, not just herringbone, and not just one sort of herd size, because larger sizes would become the main consideration. Experiments with larger herds would go into different sorts of manning. One could have double or single manning within a given parlour and there could be different numbers of units for these men to use. Experimentation beyond that stage would depend upon available resources and the results of earlier work.

MR. P. HEBBLETHWAITE (Massey-Ferguson (Export) Ltd) said that many people would be interested to learn from Dr Tomlinson what particular class of farm machinery he intended to tackle next, having already demonstrated today his interest in the herringbone parlour and front loader.

Dr Tomlinson said that the next area he would like to study would be that of mental work-load on combine-harvesters, following in Mr Zander's footsteps and also from information he had obtained from the United States. In America, work on combining had demonstrated that whilst the rate of working of the cutter bar had been increased by factors of two or three, the total work-rate had not risen by the same amount. This was because the amount of information the operator had to process also increased beyond the acceptable maximum of his capacity and one might therefore be needlessly spending money on machinery that the operator was not capable of using. The alternative was to design a machine that would reduce the mental work-load of the operator and if he could find a more suitable task of measuring the work load for the combine-harvester operator he would like to study this task. This was an area that had a great future but the problem was in defining the limits. One could measure percentage errors but it was not yet known how these related to the operator's capacity. There was a direct measure of work processing that Mr Zander had mentioned at a rate per second, but there was no standard of information processing analogous to the standard of energy expenditure in physical work-load.

DR C. K. ELLIOTT (GP) said that as a practitioner of clinical medicine his interests differed slightly from those of the speakers but they were nevertheless complementary. Specifically he was interested to see the mechanics of the assessment of physical and mental stress but he wondered if it was fair to ask when either of these stress factors became symptomatic, causing the operator to become a patient. Was there some means of assessing when in fact these physical or psychological subjective feelings became potentially disease entities?

Dr Tomlinson said he did not believe there was any way of knowing when they were likely to become disease-producing Work in the United States had considered the proportions of people in various occupations and the proportions of incidence of coronary disease, for instance, but he believed this was as far as it had gone. No work had been done on trying to assess the effects of the human being in terms of preventive measures.

MR J. ZANDER (Agricultural University, Wageningen) said he agreed with what had been said and described the case of a farmer in Holland whose experience had been that mechanisation was beneficial but mental work-loads were high. Asked why this was, a farmer replied: 'When I milked my cows by hand I had a lot of time to think about management. Nowadays, I have machine-milking and I have no time for managing'. When it was suggested to the farmer that he could think about his managing in the afternoon he had replied: 'No, in the afternoon I have to repair my machines'. Mr Zander believed that in agricultural tasks it was often the case that heavy physical work-loads were combined with medium-level mental loads and vice-versa. It was becoming increasingly necessary in the future to give attention to the relationship between physical and mental work-loads and to determining the loads in different agricultural tasks.

DR J. D. G. TROUP (Royal Free Hospital School of Medicine) wanted to know to what extent these difficulties led to men going into other types of employment or, if they stayed, whether the work was re-organized so that it was no longer as the machinery manufacturer had intended. What actually happened?

MR J. C. WEEKS (MAFF) said he had no evidence at the moment, but found it interesting that an increase in mechanisation was becoming an important factor in the doctor's waiting-room. He would like to know whether there was already evidence to show that mechanization as it existed today was producing a type of fatigue which was coming to the doctor under some other guise, and whether the doctor realized that this was a problem to which an answer had to be found. Although there was no statistical evidence which pointed to a clear 'cause and effect' situation at the moment, this was certainly something for the future and one that he was obviously interested in.

Dr Elliott said that his question had not been directed against the manufacturer; he had really been concerned with the situation in which experimental medicine could assess when certain physical or psychic loads were beginning to produce disease entities. He went on to say that he himself came from the Fens, an area where, apart from good economic development produced during the two world wars, the situation had been difficult and the pattern was one of very hard work. He had found that a man of around 45 would often present symptoms of psycho-neurotic disease which might become psychotic. It appeared that such men reached the physiological age when they began to run down but could not in fact slow down. This was the one specific thing that he had noticed, although he was not sure that it was relevant to the discussion.

Dr Troup said that with reference to milking parlours, one could predict that the mental and psychological load might produce a certain pattern of clinical pictures and he wondered if there was a recognized pattern.

The Session Chairman, **MR C. CULPIN** (NAAS), said he believed there were people who were just not able to stand up to the intensification of work in milking parlours, and he invited Miss Read to comment.

Miss Read said that one reason why she was so interested in Dr Tomlinson's work was that the very few cases which had been reported had received rather wide publicity and these had been used as an argument against the modern herringbone milking parlour and against the increase in herd sizes. One suspected that these cases were very few and that there might be other reasons for these occurrences. Dr Tomlinson, for example, had done this preliminary work on an extremely efficiently designed, controlled and well-run parlour with good labour. Unfortunately there were many who did not have that advantage. There had indeed been cases of severe stress and of people going out of farming to less demanding jobs. Miss Read said she was concerned that the facts should be established and that one should know the magnitude of the problem, which she suspected was not very great but was very real in a minor way. If there was a loss in efficiency of the herd, which was reflected in economic terms, it was possibly due to another kind of inefficiency which could hardly be measured. An operator might not be aware of any distress; he simply slowed down and became inefficient. It produced a very real economic repercussion and was something that one would like to stop.

Dr Tomlinson commented on symptomatic origins, that he believed the only thing one could apply was possibly personality testing. The question of people giving up milking probably sprang basically from personality. Personality assessment was not a very clear science at the

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ERGONOMICS IN THE DEVELOPMENT OF OPERATIONAL SKILLS

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Presented at the Autumn National Meeting of the Institution at Loughborough University of Technology on 4 September 1969

1. Introduction

In preparing a contribution for this meeting it was felt that in view of the differing interests represented among delegates, it would be necessary to establish a platform of common ground on the subject of skill development *per se*, before ergonomic implications pertaining to this process could usefully be considered.

Any cursory treatment of a subject so involved as this, inevitably carries the risk of over-simplification. This is a risk taken in the paper.

We should, perhaps, first indicate the standpoint from which we put our views. Our experience has been in the fields of Agricultural Engineering, Agricultural Education and in the training of agricultural lecturers and instructors.

A logical starting point would seem to be the definition of skill itself. For while dictionary definitions specify it to be a personal attribute, the word is also commonly used to denote a unit of activity or an element of a task.

This dichotomy of interpretation sometimes causes confusion. In the person-orientated context, the word skill embraces the human processes involved in carrying out a unit of activity. In the second context a skill is taken to be the unit of activity itself—a derivative of a progressive breakdown of an occupation into its constituent parts, e.g. an occupation is broken down into its constituent jobs, jobs into tasks and tasks into skills. It is in the former context—that of human involvement that we propose to treat the subject today.

Practical skill as an attribute is often interpreted as mere physical dexterity when in fact it is a synthesis of three distinct elements. One dictionary defines skill as 'knowledge and perception united with dexterity', and there we have it—three co-ordinated functions, implicit in any practical skill from the tying of a shoe lace to the operation of a bulldozer. We might look at these three components in more detail.

2. Analysis and Development of Skill

2.1 The Knowledge Component

Skilled performance requires a worker to know the objectives of the job in hand and the principles involved in the techniques he employs. It is sometimes said that decision-making is the prerogative of managers and supervisors and not of operatives or craftsmen, when in fact even the humblest of workers have to make judgements on their respective planes, especially in agriculture where they are left for long periods without supervision and where varying operational conditions call for the adaptation of procedures and techniques. Knowledge, therefore, is an essential component of skill and it is vital to resourcefulness and problem-solving ability.

2.2 The Perceptual Component

The use of the senses is also vital to skilled performance. The senses must be able to identify conditions and transmit meaningful information on which judgements can be made.

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The quality of an operator's performance is largely dependent upon his sensitivity to the cues each operational condition presents. Even when an operator possesses all his sensory faculties he needs to develop alertness and anticipation, e.g. the smell of an overheated engine, or a slipping belt, the vibration resulting from the loss of a flail rotor, the sound of straw wrapping around a combine cylinder, the appearance of faulty knots produced by a baler, etc.

Thus the sensing organs become a vital part of a cybernetic system—communicating information upon which the operator (a) makes his adjustments, and (b) assesses the subsequent results of those adjustments.

Clearly then, one important aspect of skill development is 'sensitivity' training (a term more usually associated with managerial functions but nevertheless apposite in this context). The trainee must be alerted as to what he should look for, feel for, listen for, etc. To leave an operator to develop these senses without guidance can be protracted, costly and sometimes dangerous.

2.3 The Physical Component

Some jobs entail movements that are simple and easy to master, but there are many more complex muscular actions which can be simplified or improved to the benefit of quality, output and economy of effort. In manual operations body posture, balance, and points of articulation are important considerations. On this subject of muscular finesse, industry could learn a great deal from the sporting world.

Stamina building in relation to particular jobs is a commonly neglected factor, and even where it is taken into account it is often done without prior consideration having been given to determining the most physically economic method of performing a particular task. The importance of rhythm, follow-through or check actions are generally left for the worker to discover by chance.

In some mechanized operations delicate and accurate muscular control is necessary with the minimum of concentration. It is in this connection that the development of the kinaesthetic sense (i.e. sensitivity of physical control transmitted through the muscular system) is important. This can only be developed by supervized practice—the objectives of which we will deal with later.

Clearly, the relative significance of the three foregoing components will vary from skill to skill—some skills being predominantly physical in character, others demanding keen perception, and others requiring intricate knowledge. Recognition of, and concentration on, the key element of a skill accelerates the attainment of competence.

Having briefly outlined the constituent parts of skill we would like now to describe the basic procedures of systematic training as applied to its development.

3. Principles of Systematic Training

Systematic training is based on a sequence of initial instruction, supervised practice and planned experience. Such a procedure assumes that one is concerned with training persons to perform a completely new task (i.e. 're-training') as distinct from training for the improvement of performance in a familiar task (i.e. 'refresher training'). In the latter case, the initial instruction phase may often be by-passed.

3.1 Initial Instruction

The first stage in providing initial instruction is that of identifying by depth analysis the precise mental, sensory and physical activities which the skills of a particular task demand.

Initial instruction in aimed at equipping an operator to achieve a given operational objective to a given standard, with confidence and safety, in preparation for a period of supervised practice.

Care is necessary in this phase to graduate the training by avoiding presenting the learner with too many activities and decisions at once. Too often one sees a learner driver in a state of confusion trying to cope with traffic, road signs, signals, pedestrian crossings and so forth, before he or she has mastered the mechanics of the clutch, accelerator and gear lever. Nothing could be more destructive to a learner's confidence.

One of the arts of training is the gradual withdrawal of external assistance to trainees, and in this connection there is considerable scope for the development and application of simulating devices.

3.2 Supervised Practice

The objective of supervised practice is that of developing further, the trainee's co-ordination of mental, sensory and physical processes, In this phase of training the key feature is 'reinforcement', i.e. the trainee should be kept constantly informed of his progress in precise terms so that he can modify his judgements and activities accordingly. The more immediately this knowledge of results is supplied to him, after an action or decision, the more rapidly his performance improves.

3.3 Planned Experience

The aim in this phase is the refinement of the trainee's performance, i.e. the development of fluency, economy of action, discrimination, the necessary stamina, and the build-up of confidence. In short, planned experience accelerates the attainment of Experienced Worker Standard.

The itemization of these phases of learning is not intended to imply a segregation of the processes, but rather to identify progressive objectives in the whole process of skill development.

Having outlined some of the basic factors involved in the development of skill we would now like to turn to ergonomic considerations, which it is convenient to treat in relation to each of the skill components described.

4. Ergonomics and Knowledge

Leaving aside the provisions made in the form of further education courses, industrial training, manufacturers' demonstrations etc. we might consider other sources of information and channels of communication.

4.1 Instruction Books

On the premise that ergonomics embraces the adaptation of men to machines, as well as machines to men, the instruction book can play an important part in this adaptive process.

We have no knowledge of any study carried out by equipment manufacturers, as to the effectiveness of their instruction books as a means of communicating critical information to equipment owners and operators. One thing is clear, however, there is great variation in the content, format and durability of the books produced by different manufacturers. We might usefully consider these three facets as follows:

4.1.1 *Content.* The content of some instruction books could well be the subject of a special study with a view to determining what information is appropriate to owners and users respectively.

It is inevitable that on occasion modifications to machines will overtake the printing of instruction books and as a result the latter are sometimes out-dated before issue. It would therefore appear that better monitoring of developments is required by the technical publications departments of manufacturers in order that up-dating of literature is maintained if only by the insertion of addenda.

The information given in instruction books would in many cases have a more compelling impact on operators if critical points related to settings, performance checks and fault analyses, were tabulated, and couched in imperative terms instead of in the more common indicative terms from which operators have to deduce what action they should take in any given situation.

While technical terms must be used for accuracy, some of these would be better understood if they were followed by brief definitions. Having regard to the target readership there is also a case for more attention to the simplification of the general vocabulary used in the text.

Credit is due to some manufacturers who make copious use of clear line drawings uncluttered by irrelevant features—this could well be adopted by many other companies.

So far as the type-set and general layout are concerned, too often one finds small type and cramped presentation both of which tend to militate against readability, especially after a day's work when some of the more enthusiastic operators like to browse over such literature.

4.1.2 *Format and Durability.* Most instruction books contain information related to both the operation of the machine in the field and its servicing in the farm workshop. There might be merit in considering a division here; one book on field adjustments and fault analysis procedures—perhaps a pocket-sized version, and the other concerned with the operator's responsibilities in terms of preventive maintenance.

It would appear that due consideration is not always given to the circumstances in which instruction books have to be used—sometimes with greasy fingers, often in wet or windy weather. When carried on machines they often reside in an oil-soaked tool-box. It is not surprising therefore that instruction books seldom last the life of the machines to which they relate. Such an important document justifies a more durable presentation than it generally gets, and perhaps the provision of a special container on the machine so that it can be kept on hand without suffering deterioration.

4.2 Other Methods of Communicating Operational Information

These might include wider use of coding methods for the identification of components and adjustments, and as indicators to servicing frequencies, e.g. colours, numbers, symbols. More durable legend labels and plaques could also be employed.

In a broader context, one often wonders how much consideration manufacturers have given to the potential of modern media such as concept film loops, programmed learning, algorits, tape or even disc recordings as means of transmitting product knowledge to owners and users.

5. Ergonomics and the Senses

We are all well aware that failure to detect faults in the performance of high capacity machines can be extremely costly in terms of commodity damage and wastage, and machine stress. The significance of sensory communication in operational skills has already been stressed, but however efficient and alert an operator may be, there are many feedback communication gaps on machines between their functions and their controls yet to be bridged, and in view of the many variables encountered in field operations such as soil and crop inconsistencies, temperature and humidity changes throughout the day, the effects of land undulations, etc., there is a need for more continuous feed-back of information from machine to operator.

In most mechanized operations, the assessment of a machine's performance is limited to the range of visibility afforded by the operator's position, and the frequency of periodic checks, for which the operator has to stop work and dismount from his machine. If things go radically wrong he may, at best, be informed by an audio warning or by the sound of an overload slip-clutch coming into action, or at worst, by the slowing down or stopping of the machine's mechanism—sometimes resulting in serious blockages and strain on the components.

Moreover, performance of a machine is not judged solely on its end product. Many tractor drivers make a first class job of ploughing, without the ability to take full advantage of their hydraulic controls. Thus the cost-effectiveness of the operation in terms of man-hours, fuel consumption and tyre wear can be of a low order. Feed-back to the operator should not be limited to visible evidence. It should also supply information to guide operation input—e.g. the ploughman should be able to 'home' on the optimum degree of weight transference.

There would therefore appear to be scope for concerted cybernetic studies in respect of both field and fixed equipment—in particular on the more complex items, with a view to the introduction of more sensing devices at key locations not merely to warn against impending blockages, etc., but also to supply the operator with qualitative information on his machine's performance.

The ever-increasing use of closed circuit T.V. for monitoring purposes in other industrial processes would suggest that the potential of this medium might be explored in relation to agricultural equipment.

On a less sophisticated plane, one ubiquitous 'sore thumb' indicator during the spring of this year was, in our opinion, the meandering tractor wheel marks resulting from field crop spraying operations. This suggests an urgent need for some kind of lateral range-finding attachment for tractors. It would have many applications to field operations requiring driving accuracy.

6. Ergonomics and Physical Dexterity

In considering ergonomics in relation to the physical aspects of operating tractors and machines, it is convenient to segregate operational controls from other adjustments which are static in character.

6.1 Operational Controls

The location and grouping of controls are on some machines well planned. On others their positioning appears to have been arrived at fortuitously—almost as an appendage to the total design of the machine. This invariably results in a less than ideal positioning of the operator, placing him in anything but a vantage point in respect of visibility and often imposing undesirable posture strains upon him.

Standardization of controls could do much to simplify the changeover from one machine to another, though clearly, complete standardization would be extremely problematical for manufacturers to implement.

The clearer identification of controls by more durable symbols would be helpful in overcoming problems arising out of the lack of standardization.

The sensitivity of controls is an important factor in the speed of developing competence and finesse of operation. Such things as steering gear ratio, the speed of response of servo mechanisms and the movement: response ratio of direct controls have a significant effect on both the development and transfer of skill.

6.2 'Static' Adjustments

Again, clear identification symbols could be more widely used, and the accessibility of adjustments is sometimes poor—often resulting in key settings being ill-adjusted or totally neglected.

Even when adjustments are readily accessible, busy operators often lack the patience to set them accurately, if the procedure is difficult or time-consuming. There would seem to be scope on some machines in current production for the simplification of adjustment procedures—in some cases by the elimination of the need for the use of spanners.

It is true that in the last ten years or so machines have come a long way in respect of the ease and flexibility of operational controls and adjustments, yet for one reason or another considerable wastage and damage still occur through faulty settings.

In a broader context, the question of operator comfort plays an important part in efficiency, in particular in training situations. People learn best when they are comfortable. When in a restricted position, especially for long periods, one is constantly fighting, consciously or unconsciously, to escape from its cramping effects. This constitutes a distraction from the critical aspects of one's work and encourages undesirable positional habits which can prove injurious, if not positively dangerous.

7. Training Techniques

One statutory obligation of Industrial Training Boards is the formulation of training recommendations in respect of all the occupations within their respective scopes. The formulation of training recommendations involves:

(i) The analysis of all activities performed in the industry in respect of both production and supporting functions.
(ii) The synthesis of the resultant elements into training syllabuses and programmes.
(iii) The establishment of target standards.
(iv) The devising of training techniques and media.

It is in the latter context that scope exists for innovation in in the fields of method study, ergonomics and cybernetics.

By examining those skills which are difficult to impart, or present a high risk factor to men, animals or machines, it should be possible to design training aids to simplify learning and compress experience into shorter time scales. This would appear to be a field of development which calls for a combined approach involving equipment manufacturers, designers, and education and training specialists.

8. Wider Implications of Training

In this brief consideration of the principles of training and of certain related ergonomic factors, the many inherent and important psychological, sociological and economic implications have been ignored. While these factors have been the subject of study for some years there is an urgent need for the intensification of this work.

The introduction of the Industrial Training Act and its resultant stimulation of training consciousness within industry, places new emphasis on the need for such studies. Accordingly there is concern within industry about the lack of reliable evidence on the cost/benefit evaluation of training.

While most employers intuitively accept the desirability of maximum performance from their work-force, the development of personnel—a vital factor in the profitability of a business—seldom receives the same degree of scrutiny as other cost centres.

The Central Training Council is very conscious of this situation and seeks to secure the kind of evidence that is needed. While the costing of training within one particular business is reasonably straight-forward the measurement of the benefits derived exclusively from that training is much more complex. The problem is even greater when one attempts to compare business with business in terms of the effectiveness of training.

The Agricultural Training Board is currently exercising itself in this field by initiating studies on the economic implications as well as on the psychological and sociological factors of its work.

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'Programmed Learning in Integrated Industrial Training'	K. SHIRLEY-SMITH (Gower)
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'Cybernetics'	WIENER (John Wiley N.Y.)

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Ergonomics in agriculture

THE HUMAN OPERATOR AND QUALITY INSPECTION OF HORTICULTURAL PRODUCE

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Presented at the Autumn National Meeting of the Institution at Loughborough University of Technology on 4 September 1969

1. Current Practice

1.1 General

For many years various items of produce, both fruit and vegetables, have been graded before sale, and with most this has involved grading for size or weight and also for quality.

In the case of apples, pears and tomatoes, and a number of vegetables (e.g. carrots and celery) grading is carried out in a packhouse immediately prior to packing, but certain other vegetables (e.g. cauliflowers, lettuce, cabbage) are graded and packed in the field as they are harvested. With some of the items, mainly apples, pears, tomatoes and carrots, the size or weight grading is carried out mechanically, but the quality inspection of all produce, and some sizing is done by human operators. Female labour is normally employed, and, particularly in the fruit packhouses, the same teams of women are engaged from year to year, so far as is possible. Although the task of classifying apples and pears is probably more complex than with any other produce, very few pack-houses have training schemes for their operators, and none make any attempt to select the most suitable operators.

1.2 Grading Standards

Voluntary Schemes designed to ensure that the quality of produce does not fall below certain standards have existed for some time, in the case of fruit for approximately 30 years, but only recently have such schemes become obligatory with the introduction of the 1964 Agriculture and Horticulture Act which makes provision for the introduction of grading standards for horticultural products. So far, five items out of a total of some 25-30 have had standards laid down; they are apples, pears, tomatoes, cucumbers and cauliflowers. In each case four classes are specified in detail (i.e. Extra, Class 1, 2 and 3). Factors taken into account in the assessment of class or grade include, for apples, for example: development and maturity, colour, shape, cleanliness, russeting, progressive defects, and non-progressive damage and blemish.

The appendix is an extract from the MAFF booklet 'Guide to the Grades, No. 2—Apples' showing the requirements for Class 2 fruit. Not all the statutory grades are always used, however, since the Extra Class is rarely seen, and Classes 1 and 2 are frequently combined, produce being all classified as Class 2.

1.3 Methods

Each individual item of produce must be inspected, and the methods for doing this includes (1) the inspection of items, such as cauliflowers, as they are harvested, with the operator who cuts the produce also inspecting it and packing it (Fig. 1); (2) the inspection of batches of produce in a packhouse (e.g. some vegetables and some fruit). In some instances, one operator may carry out inspection, sizing and packing, for instance, with finger carrots (Fig. 2) and (3) the inspection of items on a moving conveyor, as with apples (Fig. 3).

Fig. 1. Typical field grading and packing conditions.

Fig. 2. Inspection, size grading and packing of carrots.

Fig. 3. Conveyor inspection of apples.

Whereas the move towards mechanized vegetable packhouses is fairly recent, mechanization of fruit packhouses has continued steadily over the years, but there are still only two basic methods of fruit inspection in current use. The first, now being largely superseded, except for pears, involves the handling of all fruit by the operator, items being taken out of a box, or tray, inspected, and

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placed in the appropriate lane or conveyor according to grades, a system commonly known as addition grading. The more popular method, since it reduces the amount of handling of the produce and increases throughput, involves conveying the produce past the operator on a roller conveyor, which rotates the fruit as it is conveyed. The operator removes specific grades only, and a proportion of fruit is left untouched (Subtraction grading). In general fruit is fed on to the conveyor in a random manner and no attempt is made to channel it into separate lanes or maintain an even distribution. Since sizing is carried out after inspection, the operator is frequently faced with a considerable range of sizes. Inspection tables of this type can vary in size from those employing only one operator, to those employing up to eight or more.

A variety of systems incorporating the roller-type table are in use, perhaps the most common being that where all the operators on the table inspect all the fruit and classify it into all the required grades. Alternatively, in some packhouses, the table is divided into lanes and one operator is responsible for one lane, in order to avoid the items being inspected more than once. A third system requires the operators to inspect all the fruit, but select items of one grade only.

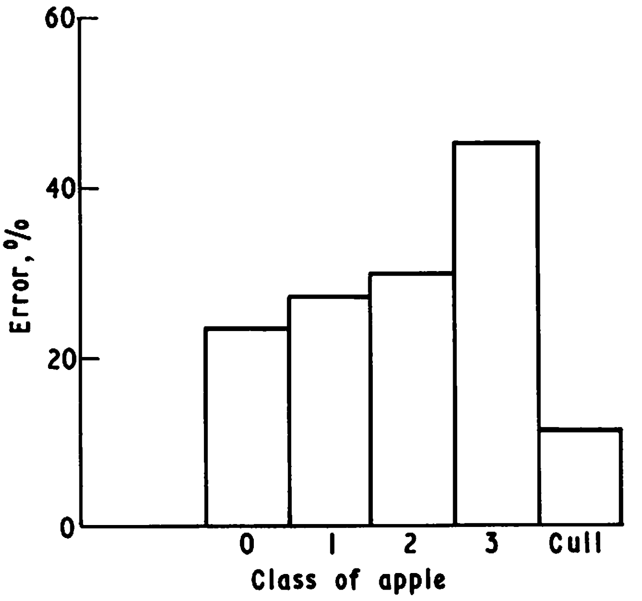

Fig. 4. Mistakes made in grading each class by hand.

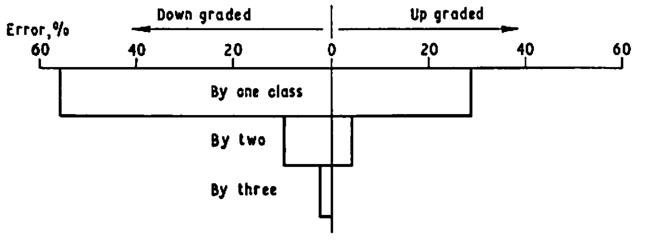

Fig. 5. Extent of errors in grading.

1.4 Operating Conditions

The range of operating conditions is considerable, and includes on the one hand all the weather conditions likely to be met in the field in winter, and on the other, the comparative comfort of a modern, well-designed packhouse. Whereas little can be done to alter the conditions in the field, apart from bringing produce into a packhouse, there is considerable room for improvement in many existing packhouses, where frequently conditions are well below the minimum required for optimum operator performance. Much of the work in both fruit and vegetable packhouses is carried out during the winter months, and ambient temperatures in fruit packhouses as low as 40-45°F have been recorded. In at least one packhouse it is the policy to keep the temperature to 50-55°F to avoid spoiling the fruit, but elsewhere temperatures of 65°F are maintained. Whereas some packhouses use ducted hot air systems, others use only radiant heaters giving very localized heating; some use heated platforms for the operators to stand on. Conditions in vegetable packhouses can be additionally unpleasant since many of the vegetables are washed, and operators frequently have to handle wet produce. With many packhouses the layout is such that produce is brought into the packhouse proper for unloading, and the continual movement of forklift trucks in and out can result in unpleasantly draughty conditions.

Lighting arrangements vary considerably, from natural light only to artificial light only. Where artificial light is used it normally consists of fluorescent tubes, but no attempt is made, in general, to use the most appropriate colour; tungsten lighting is sometimes used. The most modern inspection tables incorporate built-in strip lighting some 18 in. above the conveyor, but in some packhouses more general lighting is used and light intensity can vary from 600 Lux at the surface of the grading table in the best cases to 50 Lux in the worst.

Most packhouses use equipment which requires the operators to stand while working, although with some subtraction grading systems seating is provided, In general, however, neither the inspection tables nor the seating arrangements have been designed with ergonomic principles adequately in mind.

1.5 Operator Efficiency, Training and Selection

Little is known about the performance of individual operators under normal working conditions, either in terms of throughput or inspection efficiency, and the amount of experimental work to date is limited. However, a recent brief study of some twenty experienced apple packhouse operators indicated that consistency of classification was at best poor, and was quite likely to be very poor. Under ideal conditions, that is with unlimited time and the opportunity to handle and inspect all the fruit closely, an average of between 20% and 40% of the apples were incorrectly classified (Fig. 4). The differences between individual operators were most marked, in that at the same packhouse, one operator classified less than 20% of the fruit incorrectly, whereas another was wrong approximately 35% of the time in most grades, but in one grade was nearly 90% wrong. Most of the mistakes were only one Class in error, but some were two and a few were three Classes in error: a majority of all errors resulted in downgrading (Fig. 5).

At least some of this poor level of performances can be attributed to the almost complete lack of training given to operators. In most cases new operators are merely put to work alongside experienced workers, although one instance is known where the first day is spent learning the grades before going on to the production line. Many packhouses display either the Ministry charts showing the main characteristics of the classes, or their own comparable charts, but little is done to ensure consistent standards of grading by regular refresher courses.

The wide differences in performance between operators would seem to indicate the benefit of selecting the best operators for the inspection task. At the moment, however, no selection is carried out by the employer, although where the women work in teams there is a natural tendency for the worst operators not to remain in the team for very long. Very few packhouses even check their operators for colour vision or general visual acuity.

2. Future Requirements

2.1 General

An increasing demand is likely in the future for both fruit and vegetables, and the emphasis on high quality produce will continue and extend, both as a result of the statutory schemes and the high standards set by the large retailers. Coupled with the introduction of improved methods of packing, particularly of vegetables, and a need for greater productivity generally, this will result in an expansion of packhouse capacity and a demand for greater efficiency. The complete automation of sizing or weighing, and packing is no doubt quite feasible for most produce, but quality inspection already creates a bottleneck in many fruit packhouses, and improvements elsewhere in the system could merely make matters worse unless there are comparable improvements in inspection and grading methods. Unfortunately it is unlikely in the foreseeable future that the human operator can be replaced for quality inspection. Methods of inspecting automatically have been developed for specific characteristics such as colour, maturity[1] and internal condition,[2] but there are certain types of blemish, such as gleosporium in apples, which only the human operator can distinguish.

The main requirement would therefore appear to be for improvements both in the rate of working and accuracy of grading by the individual operators. These can be brought about in three ways:

(i) By improving the general working conditions.
(ii) By improving the design of the equipment and introducing improved techniques.
(iii) By introducing training and selection of operators.

2.2 Improvements in Working Conditions

There are many obvious ways in which working conditions can be improved, and a considerable amount of information exists, for instance, on optimum values for illumination and ambient temperature. Intensities of illumination above 500 Lux generally result in little improvement in visual acuity, and a value of 300 Lux is the recommended value[3] for the inspection of medium sized objects. The colour of the light used is important and some work has been carried out with coloured light as a means of improving the detection of blemishes on red cherries.[4]
Prior to the main inspection studies at the NIAE, brief tests were carried out at the British Lighting Council's premises using artificial apples with simulated bruises to be used during grading experiments, and also real apples having bruises of varying intensity. It was concluded that fluorescent tubes of 'white' or 'warm-white' colour were most suitable, and although colour lighting could be advantageous with a limited number of blemishes, in general white light is most effective. Brightness contrast between the objects under inspection and the surroundings is also very important and a dark background, say medium to dark grey, would be suitable. If possible it should be matt to avoid glare, which can also be a significant problem.

With the provision of local lighting immediately over the inspection table, precautions must be taken to avoid source glare and some diffusion of the light may also be necessary to decrease glare from the fruit itself, particularly if it is washed and polished. Glare from external lighting, for example sunlight, can be extremely distracting if a grading table is placed immediately opposite a south facing window.

Ambient temperatures within the working area should be 60-63°F ideally[5] although lower general temperatures are acceptable if radiant heating is used to give local radiant temperatures within the optimum range.

The noise level in most packhouses is not high, and is probably not sufficient to affect inspection efficiency.

Unfortunately with current machinery and packhouse layouts it is not easy to isolate the inspection task in a separate room, an arrangement which would make the provision of suitable conditions much simpler. With the complete automation of all processes other than quality inspection, such an arrangement might be feasible in the future. It would have the additional advantage of removing the distractions which exist in many present day packhouses, notably the movement of traffic (e.g. forklift trucks) and people within the building.

2.3 Improvements in Machine Design

Current types of inspection table could be improved in a number of ways, making use of existing ergonomic data. A first step would be the provision of suitable seating[6] where this is not already provided, and the redesign of much of what is now in use. A complementary design feature is the layout of the machine and its associated conveyors so that all relevant components are within easy reach of the operator.[7] The provision of adequate knee-room whether the operator is standing or sitting at the inspection table is frequently overlooked.

An area where there is far less data, however, is the effect of the various machine parameters on operator performance. Some work has been carried out by Malcolm and de Garmo[8] on the inspection of citrus fruit using an inspection table where the fruit is rotated as it is conveyed, and the importance has been established of the number of revolutions of the objects per foot of travel. A value of 1·6 rev/ft for each lane under inspection was found to be the optimum for spheroidal objects, and this compares with a value between 1·5 and 1·75 rev/ft per lane found during recent experiments at NIAE using artificial apples (Fig. 6). Optimum rates of throughput per operator will vary considerably with the proportion of blemished items in the sample and the complexity of the task. For citrus fruit it was found that rates between 4·2 and 5·5 items/sec were possible with 30% defectives. An approximate limit of 2 items/sec was found by ourselves with artificial apples with 50% defectives, and this is considerably higher than rates achieved in practice with real fruit. Malcolm and de Garmo also found that increasing the number of blemishes per item from one to two resulted in a reduced inspection efficiency, and the effect of multiple blemishes, as found in practice on apples must be appreciable, although no specific data is available. It has also been established that inspection efficiency is improved when the items under inspection are conveyed towards the operator from the front, rather than from the side[8]: the incorporation of such a design feature would mean a radical change in machine layout.

So far consideration has only been given to the improvement of existing types of machine. Work is being carried out at the NIAE, however, to investigate the feasibility of making quality inspection semi-automatic, by removing the need for the operator to handle the produce. Preliminary work has been done using a conventional roller-type inspection table, to which has been fitted a keyboard on which the operator registers her assessment of the grade of each apple as it passes (Fig. 7). In practice the keyboard would be used to instruct a memory system of the grade of each item, so that each could be discharged at the appropriate chute at some convenient point along the conveying system. Results so far indicate that no more than two lanes of fruit should be inspected (Fig. 8). There was little difference between 1 or 2 lanes, but the number of mistakes made in grading increased by up to 50% when the number of lanes was increased from 2 to 4. Preliminary experiments with artificial apples to compare rates of working and inspection efficiency when carrying out manual sorting and keyboard operation indicate that inspection efficiency falls off more rapidly with manual sorting, and that it should therefore be possible to achieve appreciably higher rates of throughput using semi-automatic systems.

The main problem with any system, whether manual or semi-automatic, is the presentation of the produce to the operator in the most suitable way, so that maximum opportunity is given to see all the surface area of the produce. The inspection of moving objects is not ideal,[9] however, and systems are being considered whereby the objects would move intermittently, being stationary for a brief period during inspection. Individual items could be inspected in this way, or it might be more suitable to inspect blocks of, say 4 × 4 or 5 × 5 items.

The application of semi-automatic systems to the inspection of a wide range of produce other than fruit would appear to be feasible.

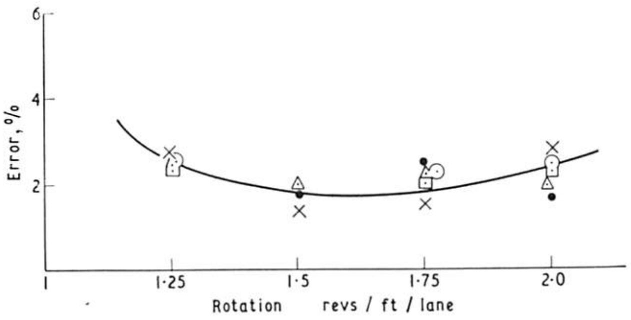

Fig. 6. The effect of rotation on grading errors with various throughput rates.

Fig. 7. Apparatus at NIAE for 'keyboard' grading expc.iments.

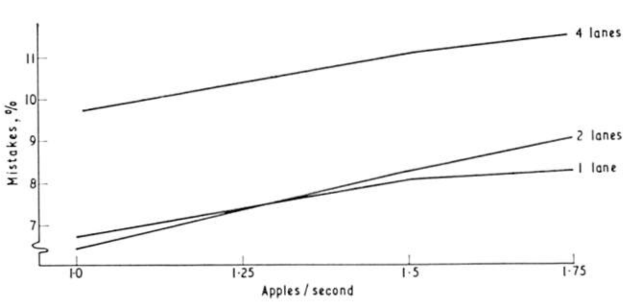

Fig. 8. Effect on grading rate of the number of rows to be inspected.

Fig. 9. Learning time (typical of performance of experienced packhouse operators, using keyboard and simulated fruit).

2.4 Introduction of Training and Selection of Operators

The human operator when carrying out inspection tasks is not noted for reliability and consistency.[10,11] Considerable variations occur between operators, and also with given operators over a period of time; in addition the length of time taken for an operator to reach peak efficiency in carrying out a complex task can be appreciable.

While there is no data on learning times for apple packhouse operators to become proficient, as long ago as 1929 Harding and Manning[12] commented on the loss of production in the manual sorting of strawberries due to the slowness of new operators in learning the task. Preliminary runs with artificial apples using the keyboard system indicated that inexperienced operators required up to 4-5 hours actual working time to become reasonably proficient (Fig. 9) that is, two full days allowing for rest periods and breaks. Further experiments with one operator only confirmed that proficiency increases steadily over much longer periods, reaching several apparent plateaux of performance of increasing efficiency. The much more complex task of grading real fruit will obviously take still longer to learn, but it might be feasible to use a grading rig with artificial fruit to enable most of the learning to be carried out before operators are introduced to the actual production line. This would be an attractive proposition should semi-automatic systems be introduced into packhouses.

The attainment and maintenance of standards of grading would be helped by the introduction of suitable training schemes, and the following proposals have been put forward.[13]

2.4.1 *The initial attainment of common standards*

It is proposed that the packhouse operators, and those responsible for the supervision of quality inspection within the packhouse (i.e. either the packhouse inspectors in the case of a large packhouse, or the packhouse manager in smaller units) should be brought together as a group.
A typical sample of apples should be supplied to the group, and individual apples be assessed by the group as a whole. If there is disagreement on the grade, this is resolved by discussion of the various features used in determining the grade, with the inspector or manager being the final arbiter. It is suggested that this type of training could take place for $\frac{1}{2}$ to 1 hour every other day for a few weeks. If common standards of assessment are to be achieved, such schemes of communal judgement and discussion are essential, but the success of the scheme will depend on the good judgement and knowledge of Ministry standards possessed by the inspectors or managers. To ensure this the separate instruction of the inspectors might be necessary.

2.4.2 *The maintenance of standards*

In order to maintain the standard of grading, the following steps are proposed:

1. A scheme similar to that described above should be operated regularly on, say, one day a month for $\frac{1}{2}$ to 1 hour.
2. In addition, prior to each day's work the inspectors or manager should select a batch of fruit, with, say, 10 apples in each grade, showing a variety of defects and combinations of defects. A brief discussion with the operators to justify the classifications of each apple should help to resolve day-to-day variations in the standards. The selected sample should then be placed on display for the operators to use as a reference in case of doubt.
3. If possible, the performance of each operator should be checked at least once daily by the inspector or manager, and the operator should be informed at once of any disagreement between her assessment and that of the inspector.

The possibility of carrying out this check without the operator's knowledge is remote, and the most practical alternative would be to ask the operator to grade for five minutes into separate containers.

It is essential for the success of such schemes that the packhouse staff are fully informed of their purposes from the outset.

2.4.3 *Selection of operators*

Apart from the use of tests for colour vision and visual acuity, it is not easy to check operators' suitability for the task before employing them. Colour charts are readily available and visual acuity can be tested using a system such as that provided by the Orthorator, although less expensive methods are possible. In practice a process of natural selection will no doubt operate, particularly where the operators work in teams, and it should be possible to pick out particularly bad operators. With the introduction of semi-automatic quality inspection it might be possible to eliminate the least efficient operators during the initial training period on a grading rig with artificial fruit. The incidence of colour-blindness among women is only of the order of 0·4%, but among males is approximately 4%.[14] Of the 12 women used during grading experiments one had slightly defective colour vision. On this evidence, the elimination of potential inspection employees with an indication of colour vision deficiency should not be unduly restricting.

3. Conclusions

Since the human operator will be used for quality inspection and grading for some time to come, and the emphasis on high quality produce, both fruit and vegetable, will no doubt increase, as will the demand for greater productivity, there is a need to improve operator efficiency. This can be achieved in three ways:

1. By improving working conditions.
2. By improving the design of existing types of machine, and introducing improved techniques, making use of automation wherever possible.
3. By introducing methods of training and selection of operators.

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Appendix

Class No. 2 is designed for apples of reasonably good quality which, because of defects of colour, shape or blemish, cannot meet the requirements of the higher classes.

Characteristic	Requirement
Variety	All apples within a container must be of one variety.
Development and Maturity	Must be sound both internally and externally. Must be reasonably firm, no more than very slight shrivelling being visible. Dessert varieties must be sufficiently mature to ensure subsequent ripening and the state of ripeness of all apples must be such as to allow them to remain in reasonably good condition during the normal period of distribution.
Colour	*Red dessert varieties* must not be completely devoid of characteristic colour.
Shape	Defects allowed provided the general shape characteristic of the variety is retained. Very pronounced 'King' fruit must be excluded.
Cleanliness	Must be reasonably clean.
Progressive Defects	Must be free from any blemish or injury which might seriously affect keeping quality.
Non-Progressive Damage and Blemish	Damage and blemish not affecting keeping quality must not exceed 240 mm^2 ($\frac{3}{8}$ $in.^2$) on dessert varieties or 320 mm^2 ($\frac{1}{2}$ $in.^2$) on culinary varieties. The stalk may be broken or missing but there must be no visible evidence of decay or mould. Additionally, bruises not more than slightly discoloured may be present; their total area must not exceed 320 mm^2 ($\frac{1}{2}$ $in.^2$) on dessert varieties or 640 mm^2 (1 $in.^2$) on culinary varieties. If there is no other damage or blemish then the total area of bruising with slight discolouration may be 480 mm^2 ($\frac{3}{4}$ $in.^2$) on dessert varieties and 960 mm^2 ($1\frac{1}{2}$ $in.^2$) on culinary varieties. The amount of damage present must not seriously detract from the overall appearance of the contents of a container.
Russeting	Russeting with small dry cracks is allowed provided it does not seriously detract from the appearance of the apples. Any cracking present must be shallow. Up to three cracks will be allowed provided that no one crack exceeds 15 mm ($\frac{5}{8}$ in.) in length and that total cracking does not exceed 25 mm (1 in.) in length.
Sizing	*Dessert varieties.* Not less than 50 mm ($1\frac{15}{16}$ in.) maximum transverse diameter. *Culinary varieties.* Not less than 60 mm ($2\frac{3}{8}$ in.) maximum transverse diameter. The difference in diameter between apples within a container if packed in rows or layers, must not exceed 10 mm ($\frac{3}{8}$ in.) for dessert varieties or 20 mm ($\frac{3}{4}$ in.) for culinary varieties. The minimum size packed must be stated on the container. Apples packed loose in a container may be of mixed sizes. □

DISCUSSION (First Session)
—from page 36

moment but he believed this was the only sort of help that could be offered.

MR T. C. D. MANBY (NIAE) congratulated Mr Zander on his use of simulators and the development of them. It appeared that Mr Zander was using signals to replace the crop and indicate the movements required for the header and the reel. Mr Manby said that in his own limited experience of driving combines, he had always found that the most difficult task was the control of the reel in a laid crop. He was not convinced that the simple signal that was displayed required the same judgment as was required to operate a reel efficiently when driving a combine in difficult conditions. He wondered whether the technique of using film as practised for car driving simulation when devising controls on cars, had been tried out for combine harvesters. If he were tackling simulators, he would want to go about it this way from the beginning. He would be interested in Mr Zander's views.

Mr Zander said he had considered the possibility of using films; although Mr Manby had said this was simple, he believed they had found a more simple way. For indoor experiments, students had mostly been used who were not acquainted with combine harvesters. On the other hand, in the fields experienced men had been used and thus the difference between inside and outside experience was emphasized. It had been decided to start indoors with people who were acquainted with combine harvesters but were not skilled drivers. Next, one went into the field with very experienced drivers. Subsequently, the outdoor men were asked to come to the laboratory and do the same task. It was particularly noted that the level of familiarization was very high; these men were quick to become acquainted with their machine and, even with the more practical type of man who worked in the fields, one achieved the same results. Experiments were developed based upon eight outdoor men and then indoor experience based upon twelve students. For the 'practical' men variances of correlation were plotted. Very good correlations resulted from these experiments. Consequently, in discussing the use of films, it had been felt that as those working on the simulator could arrive at much the same figures as those who were experienced with combine harvesters in the field, familiarization in practice was to be preferred to the use of film.

Mr Hebblethwaite felt that Mr Zander's paper had dealt too summarily with combine harvester cabs. It might be that in the cabs that Mr Zander had tested, no significant effect on noise level had been established but potentially sound insulation could effect substantial reductions in the noise level to which the operator was exposed. On the matter of selecting future tasks, including work on combines, Mr Hebblethwaite suggested it should be on the basis of the economic background and utilization factors of the various machine classes. In many parts of Europe the average annual use of a combine was less than 100 hours. The symptoms in any one year hardly had a chance to show themselves. The effect of dust on combine drivers was a case in point. In general, only asthmatics and people who were naturally 'chesty' were troubled to the extent that they had to see a doctor. Work should be done in this area to establish the economic influence, or workdays lost per annum. However, in agriculture the statistic would not provide the total picture.

Dr Tomlinson argued that the fact that men did not go to the doctor was not a sufficient cause for complacency. He believed there was in fact good reason for work being carried out on dust measurement. Effects went on from year to year and although the man was only exposed for a very limited time, he might go to the doctor after ten years and then find that he had a chest disease.

Mr Hebblethwaite said he had wanted to distinguish between industry and agriculture. In industry it was easier to establish whether a problem existed because exposure was for twelve months in the year.

Mr Zander agreed that 100 hours per annum was about the maximum amount of usage for a combine harvester. In terms of ergonomics, his research projects had approached it from the point of view of the entire system of man and machine within 100 hours per annum. It was therefore necessary within this framework to have a very high capacity, free from trouble and with a favourable load.

Thus, when referring to the cost of the suspended seat, it was desirable to draw attention to the whole layout, including the consideration that the man must be trained and instructed very well. He had to reach a high level of efficiency at this stage and this was the reason that he had placed such emphasis on learning activity or the learning characteristics. It was as important from the engineering as from the medical point of view, looking both at the output and the performance, that the job should be accomplished non-stop and at a high level with a favourable load, especially with such expensive machinery as combine harvesters, milking machines and the like. □

Ergonomics in agriculture

DISCUSSION (Second Session)

Chairman: J. C. MATTHEWS, BSc, FI AGR E*

Presented at the Autumn National Meeting of the Institution at Loughborough University of Technology on 4 September 1969

MR G. N. STEVENS (NIAE) said that as standards among pack-house operators appeared to be so low because of their having not been properly trained, he wondered just how much training the Ministry Inspectors themselves had been given and whether one could expect the same inconsistencies.

MR LOVEGROVE (AHFITB) replied that what particularly interested him about this problem was where people in the pack-house, who were perhaps inexperienced, were suddenly confronted by a variety of decisions. They had to make a decision on grading by shape, grading by colour and grading by blemishes, all at the same time. The operative on the production line would find himself faced with green ones, red ones, big ones and small ones, some with bruises, others with cuts, coming at him in a steady flow and he would be baffled. This was known in a training situation as 'dazzle', with everything coming at him at once. The way to overcome this would be to train the man by stages. First of all he might be given the situation where he was grading only by shape, until he arrived at a standard which was considered acceptable. Then one could let him grade by colour alone until he reached an acceptable standard and finally combine the two, colour and shape, possibly bringing in blemishes as well, so that one gradually built up his stamina and ability to do the job. Knowing the standards was one thing but being able to make quick decisions based on those standards with material being fed through at a rapid rate, was a different matter and this was where training was important. The grades that the Inspectors dealt with was a matter of knowledge; they knew the grades and they could assess them in their own time. It was in the production line sequence that the problem

*Programme Convener, I Agr E Autumn National Meeting 1969.

arose because of the need to make these decisions at a certain speed.

MR J. MATTHEWS (NIAE) said that the lack of uniformity to which Mr Stevens referred was one of two main influences in the actual performance of the conveyor belt. He believed the other one was the limitation of the machinery itself which probably resulted in the situation where the operator, sitting in one position, could not always see the whole of the apple. He wondered if Mr Stevens had any information on the existence of this problem and any other machine limitations as distinct from problems of training.

Mr Stevens replied that it was a fact that the operator could not see the whole surface area of all the apples. In a pack-house the operators tended in practice to ruffle the fruit to give themselves the maximum opportunity to see all the surface area but there must be many blemishes that got by. A very brief assessment on an experimental machine, to measure how many blemishes were escaping unseen, had produced a measurable number and a way in which this problem could be overcome was only by developing improved methods of presenting the produce to the operator and making sure that he had a chance to see the whole surface area. Mr Stevens said he must confess to a feeling that grading was too complicated. Although there were four basic grades, in practice, one of these was rarely used except in special categories, and quite frequently classes I and II were combined. But the number of different classes still raised problems and he believed there were too many at present.

The Open Forum Chairman, **Mr J. Matthews,** commented that the day's programme had been deliberately restricted to those aspects of ergonomics that dealt with the scientific analysis of work in machine operation and the development of skills. It was probably true to say that the other large aspects of ergonomics such as the occupational hygiene aspects, noise and vibration, dust and fumes, has been covered fairly fully in recent Institution Conferences, particularly the Agricultural Engineering Symposium at Silsoe in 1967 and the earlier Annual Conference of the Institution in London. This did not mean, however, that the problems in those areas had been solved, and obviously future conferences would come back to noise and vibration again. Mr Matthews hoped that in this forum one might accept discussion on the occupational hygiene aspects and at the same time also discuss the aspects covered by the papers today. His own proposal was that one should take separate themes in order to give some sort of structure to the discussions. He proposed that the first theme should be 'Environment', followed by 'Ergonomics in Machine Design', then 'Working Methods' and finally, 'Training'. In all four of these topics points had already been made which had either not been developed fully or one had sensed that there was something more to be extracted from them.

With regard to environmental and occupational hygiene aspects of the subject, Mr Matthews pointed to noise and vibration as being the two principal problems which had been encountered, identified and worked on. They had certainly predominated in the early application of ergonomics to agriculture. He believed the present situation was that one could now suggest some of the palliatives to these problems, but the stage had not yet been reached where these palliatives had been generally accepted and put into normal use; in that sense, the problem still existed, and of course there were other areas where the palliative had not yet been completely discovered and outlined. Thinking of noise, it was clear that tractor noise-levels were still unsatisfactory. Mr Matthews also suggested that a situation existed in many farm buildings housing processing plant or even, in some cases, animals, where there were unsatisfactory noise-levels for the occupants of the buildings, This noise level even led to complaints from the local communities. This might become a worsening situation.

With regard to tractor vibration, it was frequently this factor, rather than the power availability or implement capability, that limited the output at which the tractor was driven. One probably also had a situation where damage was being caused to spines and stomachs by vibration or other aspects of tractors, although in the UK this judgment was based on little other than subjective evidence of knowing people who had these complaints.

Mr Matthews hoped the discussion would establish whether there were in fact other problems he had not mentioned at this stage and which had not yet been identified and investigated. He would also like to hear opinions as to whether those things he had particularly mentioned could be left for solution by manufacturers and others responsible for equipment or whether Government should come in and legislate for acceptable conditions. Mr Matthews also hoped one might discuss how it could be ensured that in an industry so diverse as agriculture, there would be some means of detecting this type of problem in future so that something was done about it at the right time.

Mr Weeks said one frequently found when dealing with problems of safety that cost came into it. While everybody felt that safety was a very good thing and the manufacturer would be quite prepared to apply it to his particular piece of equipment, he would price his product out of the market if his competitors did not take the same steps. Everybody was aware of the problem of noise, but one wondered whether the manufacturers would be prepared to do anything until required to do so by legislation. Mr Weeks said he would be very interested to hear what the manufacturers had to say about this.

PROFESSOR W. F. FLOYD (University of Loughborough) said he did not really agree that it necessarily cost money to put safety into design. It was expensive to add safety to an existing design, but it did not necessarily cost money to put safety into a basically new design. Indeed, with proper thought it was sometimes possible to achieve safety and save money. Professor Floyd said he disliked legislation on safety other than in the broadest possible terms, but he agreed that for existing machinery it would cost money and probably would require some legislation.

MR P. F. C. SCOTT (Massey-Ferguson (UK) Limited) said he agreed with Mr Weeks that a manufacturer could supply what a customer wanted. It was the manufacturer's job to do this and was in the long-term interest of the manufacturer to do so. It was true that if one started with a blank sheet of paper it did not necessarily cost money to incorporate a lot of the things that one knew needed to be done. But one did not usually start with a blank sheet of paper, as machines were usually evolved from existing designs. This being so, it was going to cost money. If he could be convinced that the customer, without legislation, was quite prepared to pay this, the manufacturer would do it like a shot. Mr Scott said he was sure all the main manufacturers were working towards all of these things, but it could not be rushed because in that event it would cost a lot of money all at once. These things had to evolve fairly slowly in the first instance. In his organisation, legislation was not necessarily looked upon as a bad thing. Government had to give guidance as to what future legislation would be because manufacturers, particularly international ones, were looking some five or ten years ahead in the design of their machines. It was not just the UK that one had to think about, but perhaps noise-levels in Sweden and safety regulations in Germany or in France, and at what the attitude was in North America. All these had to be considered and put into designs. Where one was able to achieve a unified approach to legislation in a lot of countries, it helped the world-wide manufacturer enormously.

MR HILLIER (Ford Motor Company) said that an underlying factor in all of this day's discussions, and one which Mr Zander had particularly highlighted, was that if the improvements and information discussed by the speakers were to be really useful, they must have this economic accent. There must be information as to the sort of saving which could result. It would be helpful if one could say that in improving the performance of the operator, output could be increased by a given amount. It would then be possible to work out the cost in terms of the improvements that would be gained. In other words, ergonomic information should be supported by economic information.

Mr Lovegrove said there were many interested parties involved in the subject of ergonomics. On whom did the onus really rest? If the respective interests of all parties were defined, the next step would be to collect and study all tangible evidence in existence of the need for action to be taken. Then, looking at the magnitude of each problem one could consider both its human and its economic significance.

Mr Matthews said he believed that many working on these problems in the field were conscious of the shortage of quantitative information on the extent of the problems. It was known, for example, that dust was a problem in many plant situations. What was not known was how many men were involved, what the effect would be in terms of their inconvenience, their dissatisfaction with the job and their health record. To some extent this led on to a point he had made earlier as to how one could ensure that there was the means in the future to identify these problems and present them to those engineers or ergonomists who were able to put their efforts into this field.

Dr Elliott said he thought that part of the answer to what had been said lay in the evolution of the health situation in this country. He did not wish to make a direct criticism of the National Health Service but the country did lack an occupational health service at State level. In industry such a service often existed, and the feedback in industry came from industrial medical officers employed by firms, who were there to see the problem and report on it. In the agricultural field no such service was in existence at all and he felt this was partly responsible for information being so limited. Dr Elliott went on to say that as farmers were obviously the people that used machinery and employed the services of men, he would be interested to know how information was got over to them. At one meeting where he had dealt with rehabilitation in agricultural areas, only one farmer had been present and he had been disguised as a peer and a member of the Regional Hospital Board.

Dr Tomlinson referred to the tractor operation survey which had been designed to try to isolate some of the problems that were occurring amongst tractor drivers. They had discovered that not only with noise and vibration but with other factors such as glare and dust, there was a lack of quantitative evidence. Dr Tomlinson said he would not like to attempt to put any economic value on the results obtained; many of the factors interacted upon each other. Age for instance, could interact with an operator's opinion of ride comfort and although there had been a closer definition of the field that should be studied, it did not give the complete answers to the problems. He referred to another survey that was being carried out with regard to noise in buildings and he would like to see other areas investigated where the main problems had been inferred and what types of machinery were the main culprits.

Mr Matthews agreed that there ought to be a multi-stage approach. One began with heresay and opinions and then one tried to go into the quantitative survey to get some better idea of the problems. This had possibly to be followed by a quantitative survey whereby one used instruments on the selected sample of people to determine the problem conditions and the numbers of workers involved in precise terms.

MR J. M. CHAMBERS (Retired) said he believed that in some overseas countries the workers' unions had insisted on certain things in farm mechanization for safety and comfort; they had got on with the job and done it. In Sweden they had insisted on safety cabs. The rest of the world was still discussing this ten years later when probably in this country if the same steps had been taken as in Sweden, a lot of people would be alive today that were now under the sod. Was it not the case that a lot of the problems could be approached directly in this way? The men knew what they wanted so why did they not put their foot down and then all the manufacturers would have to provide what everybody knew was necessary. Instead of that, it had been necessary to convince a lot of people outside the industry altogether; the necessity was to achieve common action at the same time.

MR A. E. CALVER (National Union of Agricultural and Allied Workers) said it was pleasing to hear that other people were interested in safety, especially in the safety cab. Members of the NUAAW had for a great number of years been putting their foot down firmly from one end of the country to the other regarding safety and they were determined to get the safety cab in the future. This would be by legislation and it was his own view that any safety measure should be by legislation. Of course, the manufacturer, by putting certain safety measures into his machine, would have to put up his price and the other manufacturer who did not put it on would be able to keep his price down, but it was not only the question of economics. There was also the fact that once the machine got on to the farm, if there was no legislation, safety equipment would be taken off. There would be no liability to use it. Mr Calver said that in all of our safety regulations, the liability had been both on the person that owned the machine and the person who used it and he believed this had been a very good thing in the past. He knew of one or two members in his Branch that had almost been summonsed for using machinery that had not had adequate safety measures on them. He was certain that we could see that safety measures were necessary and that they must be legalized to bring them into operation and run them efficiently. When one looked at past legislation and discovered that even the much-used farm ladder had had to be brought within safety regulations, one realized how necessary legislation was.

Mr Matthews commented that it was true that Sweden was taking the lead in many of these things. Some might perhaps say that they were going too fast in some areas and that it was clearly possible that one could legislate before the required conditions could be practically achieved. It would remain to be seen during the coming years when a whole new series of additional regulations would be coming in, whether in fact they had been too rapid or whether they had done it at the right time and would achieve the measure of control that they desired through their legislation.

Mr Matthews said he would now like to move the discussion to the theme of machine design. This had been featured in the paper by Mr Zander who had described how ergonomics could help to optimize the design of the machine. Mr Matthews said he still found himself with the problem of knowing just how one sealed the gap between the researcher working in the university or the research institute and the manufacturer, who had the same enthusiasm for making the best machine, and who perhaps could not at this stage use all the techniques that had been described but would like to play his part and use some information gleaned from research in designing the machine. It would be interesting to hear from any manufacturers represented at this meeting about particular problems of using what already existed or what was coming forth now among ergonomic data, to indicate whether or not the experiments being conducted were providing the data in the right way. How far should researchers go and how far should people working in ergonomics go in considering machine design, to arrive at defined standards for control layout, control markings, seat design and so forth? To what extent should these things be left to the inventiveness of the individual manufacturers? A particularly interesting point on this had come from Mr Zander's paper, concerning the use of simulators of various types. Perhaps Mr Zander would like to say whether he could see the simulator being applied to tractor design, for example.

Mr Zander said it was easier in his country in the sense that they did not manufacture combine harvesters in Holland, so it was necessary only to look at what people had bought. He believed that proper attention should be paid to education and training, so that the young engineer who joined in their research projects would have the ability to work with available and applicable ergonomic data. In the matter of simulation in a particular field for the purpose of obtaining data about modifications or alterations that it might be necessary to make, the training and selection of operators was important. In answer to a question, Mr Zander said that investigations in the field had supplied evidence of strong correlation between the ability of a person to learn the task quickly and their subsequent performance efficiency.

MR R. M. CHAMBERS (Massey-Ferguson (UK) Limited) said, in connection with learning, that he had some farmer friends who insisted that two or three weeks before the harvest was due, their drivers went out with their combine harvesters into a grass field, where they were able to get used to handling the controls. This type of learning gave them an advantage when they did eventually start harvesting. It was something quite worthwhile for farmers and it took no more than one hour per day for two weeks before the harvest.

Mr Evans said that this was again a matter of phased learning by means of the step-by-step procedure. One became familiar again with the controls of the machine before actually going into the crop and doing the harvesting. It certainly seemed that people came to a stage of competence in a shorter time. An interesting example was provided by a simulated training unit used by the Construction Industry Training Board in Norfolk. They had an indoor sand-pit with four digger units, working in the sand face. The engines were outside the building so there was a hydraulic drive from the engine to the digger. The instructor could therefore stand beside the operator in a quiet situation and speak to him in a normal voice while the operator carried out his various tasks. What was so valuable was the fact that one could talk reasonably quietly and carry out the job without the normal noise and vibration that one had from the actual working machine. There did not seem as yet to be any reliable information to tell how much quicker this learning process was but the feeling was that it was extremely valuable to provide this simulator for initial training. Having thus familiarized him with the basic handling of the controls, he could then be taken to a working situation and put on the digger itself.

Mr Matthews said he was sure this was a good point but unfortunately many of the situations requiring training in agriculture involved the use of the combine harvester or the tractor, which were moving all the time; the visual input of the operator was very difficult to simulate. The example with sand inside a building was relatively easy to simulate fairly realistically. Mr Zander had indicated that in the case of the combine harvester one could simulate the visual input fairly crudely by having lights to which the man had to respond. Mr Matthews doubted whether enough had been done at the moment to indicate how far one could take this approach in training. Although it might well work for combine harvesters, simulation of visual inputs in tractor operation would be much more difficult to simulate. Some thought had been given over the last few months as to whether a tractor simulator facility should be established. One could certainly think of several experiments to do on it which could be valuable. However, one realized how complicated aircraft simulators were, where the pilots only looked through a small window. Motor car simulators became more difficult because the field of vision was a wider view to the front and a mirror to the rear. On the tractor, the man looked all around at various depths of view and this made it a very expensive simulator to develop. It would be interesting to hear views on the practicability of this and ways around the problem, from the manufacturers' point of view. He wondered whether they felt that such an approach was likely to be justified, bearing in mind that the development of the facility could cost tens of thousands of pounds.

Professor Floyd said the fact that the motor car had not been successfully simulated gave an indication of the difficulties of designing accurate simulators. Even if it would pay to have a good motor car simulator as Mr Zander had said earlier, one could effectively design a simulator only when one knew what it was that one wanted to simulate; in other words, when one knew a lot about the task. At the moment it was not really known what the man on the combine harvester was trying to do. People had different ideas about what were the really significant cues. When this problem had been solved, then any engineer could go away and design a simulator because he would have been given a specification. To illustrate the point, a very good simulator had been devised for testing respirators. The type of respirator used in aircraft, and for military applications of one sort or another, was designed as the result of a great deal of work having been done on the physiology of respiration and this work was brought together and put into the design of a good simulator. This now existed so that engineers could use a simulator on the production line for testing respirators. This illustrated the point that when one really knew what the task of combining amounted to or what the task of driving a tractor was about, then simulators could be built which could be used for testing or carrying out further studies without going into the field. Professor Floyd said that in the long run he still felt that one had to go in the field; what simulation really saved was a lot of preliminary field-work, so that ultimately carefully planned field-work could be based on earlier simulator studies.

Mr Matthews said he would now like to move the discussion towards the concluding two themes that he had mentioned in the introduction. One of the points that had not been developed was the further application of instrument monitoring machines. Mr Matthews said that his own personal opinion was that we should see more of this in the future. It would be interesting to hear any opinions on the desirability of further operation monitors of an instrument nature, or of some other nature, to help the man to obtain better information of how the machine is performing.

MR H. F. HOWELL (Massey-Ferguson Limited) said he had been interested in what had been said during the morning session about stress levels to operators. One could understand about an 'average man' in regard to dimensions, and loadings for hand and foot controls, but it would be useful to know a little more about mental stresses operators were being subjected to. This was a difficult subject because everyone was different, some people being able to go through life in a very happy-go-lucky manner and nothing seemed to bother them, whilst others worried about the slightest thing. As mental stress altered the effectiveness of the operator, was there any common denominator for an average man's mental stress levels?

Dr Tomlinson said that as far as mental stress went there was no absolute rule by which one could abide, even for a specific individual. This was the great problem in milking studies where peak-loads had been identified but it was not possible to say where they were in relation to that person's capacity. So far as could be seen at the moment, the only way to do this was by getting some objective assessments of a large number of tasks and one could probably measure the information processing capacity required by some of these tasks and put it into an absolute unit as Mr Zander had described. Dr Tomlinson said that he knew of no absolute unit that would be really satisfactory for this and he could not see one in prospect for the next few years.

Dr Troup said that very little was known about the way people actually used their bodies to exert forces upon an external object, and there was a great deal of research work to be done, not only on defining physiological and psychological variables but on selecting the right one to use as a parameter for research in a particular design project.

Dr Tomlinson said that when dealing with the particular problems under discussion, one was not only interested in getting measurements at peak-loads; somebody had to get down to the more fundamental problems, even though the useful results may be many years away.

Dr Troup said he thought one of the difficulties was that more stimulus was needed to do these things. He had been profoundly depressed by an earlier contributor to the discussion who had said, in effect, that it was not commercially expedient to start with a blank sheet of paper and this meant that ergonomics could only be applied on a rather 'ad hoc' basis. It appeared that one could try and improve the situation only in a given framework for a given system, but what made ergonomics come really alive was when it was taking part in a new design process.

Mr Matthews said that in his opinion one thing they would never encounter was workers who recognized that they had a high mental work-load, saying that they did not want the job for this reason. Symptoms of an unsatisfactory situation were much more diverse. There were escape routes which were normally taken, probably quite sub-consciously, by the individual who did not want to admit that he was not up to the job in hand.

MR. O. J. H. STATHAM (Potato Marketing Board) said he was interested in quality versus quantity in a worker's output. It was obvious from some of the facts in Mr Stevens' paper that workers' performance in assessing grades of potatoes or apples was fairly appalling and one wondered whether it was worth doing the task at all if this was the sort of level which was achieved. The speakers this morning had said that where an excessive number of judgments had to be made, the worker in fact reduced his work output in order to cope with this. Mr Statham asked whether, in the specific case of a grading table, Mr Stevens thought it should be within the worker's power to be able to control the rate of flow of produce towards him in order to improve the quality of his work rather than the quantity of the throughput. As far as most vegetables were concerned, control of speed of operation appeared not to be within the operator's hand and there seemed little point in continuing with this grading process if one was not going to achieve the sort of standards which one had laid down on paper.

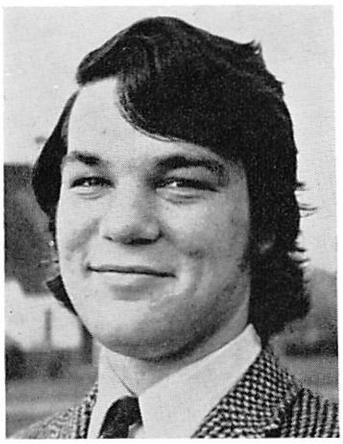
Mr Stevens agreed that this problem had crossed their minds when they had begun work on quality inspection grading. After having talked with the Applied Psychology Unit at Cambridge they had learned that performance was in fact likely to go down if the operator was able to pace himself. This was for the simple reason that the operator did not take the opportunity to slow down if he could pace himself, but instead he speeded up and as a consequence his efficiency dropped rather than the reverse. It was far better for an operator to be paced and have no control over throughput. It was disturbing to find how poorly these operators were performing in practice in the apple pack-houses and yet nobody, so far as was known, had complained about the quality of the produce coming out of the pack-houses, which again made one wonder whether it was all worthwhile. An important point that had been mentioned earlier on was that there may well be far too many grades. It could be better to reduce the number of grades and simplify the system of grading. If one was after absolute consistency of grading then this would be essential. Mr Stevens said he thought it was essential that there should be some control over the throughput on the machine. The quality of the sample coming into the pack-house or potato packing shed varied enormously and the pack-house manager must be able to regulate the throughput to match the quality of the produce. If there was only a small proportion of blemished produce then a much higher rate could be used and conversely if the proportion of damaged produce was high then the rate would have to be cut down. Not all pack-houses had this facility; some of them operated their machines at a fixed throughput.

Dr Tomlinson said he thought this question of slowing the production line down was merely attempting to gloss over what was basically an inefficient method. The basic problem was one of training. Professor Floyd had mentioned this and it was generally true with all inspection tasks, but there had been some successful attempts in industry to adopt proper training procedures. It was just as difficult to maintain the standards achieved. What was often forgotten was that it was not just a matter of simply developing a skill but of maintaining it; this was vitally important. With a machine tool, for example, one was always getting feed-back on how one was doing. If it was a reject, one knew it, and if it was good one could see that it was good. In grading produce one did not get this feed-back; one graded something and it went away. It was vitally important that having trained people to do these inspection tasks correctly they then be given knowledge of the results of the grading. □

SCHOLARSHIP AWARDS IN AGRICULTURAL ENGINEERING

The following awards have been made in the gift of the Institution to the following full-time students of agricultural engineering, during the academic year 1969–70.

THE DUNLOP SCHOLARSHIP



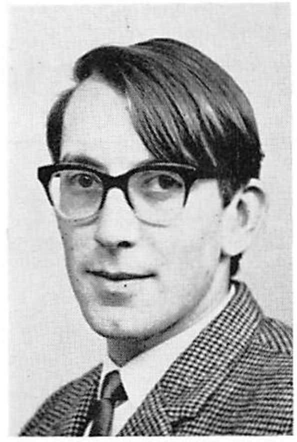
Mr P. C. Bennett

A Dunlop Scholarship was awarded to 21-year-old **Mr Peter Charles BENNETT.** Following a grammar school education, Mr Bennett underwent a Student Apprenticeship at Ford Motor Company and acquired an HNC in Mechanical and Production Engineering at Barking Regional College of Technology. After that he spent some time with ICI Plant Protection Limited which took him to September 1969 when he began his present post-graduate course in farm machinery design at the National College of Agricultural Engineering.

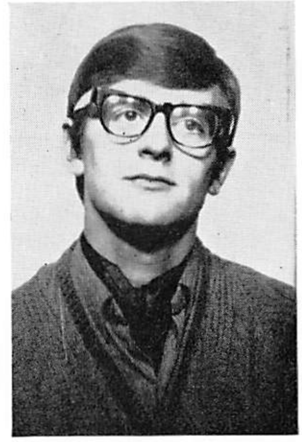
Mr Bennett's hobbies are very varied; in his own words, they range "from music to motorcycles". Possibly the latter have trumpet exhausts. He also likes fishing, painting and rock climbing, the latter no doubt figuring in an Outward Bound course in which he took part in 1966.

SHELL MEX AND BP BURSARIES

One of the three recipients to receive a Bursary was **Mr David John Michael JONES,** aged 28, who comes from Cambridge. For three years after leaving school he worked for Chivers Farms Limited and then studied full-time at Riseholme College of Agriculture. Following this he gained some useful experience with Achurch & Son (Horncastle) Limited and later with J. J. Rainthorpe Limited. Then he took up his studies again, this time at Lackham School of Agriculture where he secured his City and Guilds 260 and 261 Certificates.



Mr D. M. Jones



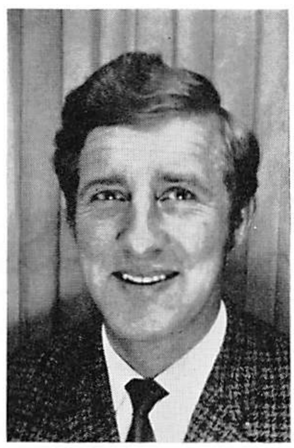
Mr B. A. Moseley

From there he entered the ND Agr E Course at West of Scotland Agricultural College, where he is now.

Hobbies include cars, hunting and shooting, provided these have not all been put paid to by his getting married last July!

22-year-old **Mr Brian Alfred MOSELEY** also received a bursary to help him along with his studies for the ND Agr E. He is doing the course at Essex Institute of Agriculture where he fits in the time somehow to be Secretary of the Agricultural Engineers Society. He started life in Lancashire and secured an NCA and NDA from Lancashire College of Agriculture, having already built up some practical experience of mixed farming in Cheshire, Yorkshire and Devon.

Mr Moseley is fond of music and abstract art and describes one of his hobbies, rather mysteriously, as "practical inventiveness". This conjures up visions of magnificent men in their farming machines, trundling the by-ways of Writtle!



Mr K. P. Woods

The third Bursary winner is **Mr Kevin Patrick WOODS** who originates from Northern Ireland. Following a three-year course in Mechanical Engineering and Machineshop Technology at Macclesfield College of Further Education, he became an instructor for the Irish Department of Agriculture, working at Salesian Agricultural College, County Limerick, for several years. Thereafter, he completed the two and a half year Diploma course in agricultural engineering at Chelsea College and then went on to West of Scotland Agricultural College where he is on the ND Agr E course.

Mr Woods, who is 34, is keen on steam model engineering and he likes music, including singing—whether his own or other people's is not clear. His list of interests also included "flying football" but a missing ampersand is suspected. Also Yoga. Which might account for the missing ampersand, who knows? □

admissions and transfers

At a meeting of the Council of the Institution on 27 January 1970 the following candidates were admitted to the Institution or transferred from one grade to another, as stated below.

ADMISSIONS

Fellow

Dimmick, R. G. A. .. .. *Warwicks*
Matthews, J. .. .. *Beds*
Murray, P. A. M. .. .. *Glos*
Roy, S. E. .. .. *Peru*

Member

Barnett, I. R. .. .. *Stirlings*
Burley, S. D. .. .. *Warwicks*
Chowdhry, B. A. .. .. .. *West Pakistan*
Stokes, D. J. .. .. *Staffs*

Associate

Arnold, O. T. .. .. *Northants*
Bates, A. J. .. .. *Salop*
Black, G. F. .. .. *Lancs*
Buckley, M. W. .. .. *Warwicks*
Jeffery, H. J. A. .. .. *Devon*
Owen, J. E. .. .. *Cambs*
Ramsbottom, M. .. .. *Lancs*
Todd, F. S. .. .. *West Germany*
Weeresinghe, P. A. .. .. *Ceylon*

Graduate

Constantinesco, J. A. G. .. .. *Westmorland*
Hancox, W. H. .. .. *Notts*
Jones, T. C. .. .. *N Wales*
Junker, H. B. .. .. *Somerset*
Moore, A. E. .. .. *Worcs*
Morgan, J. B. .. .. *Brecon*
Pringle, R. T. .. .. *Aberdeens*
Wain, R. H. .. .. *Oxon*
White, R. G. .. .. *Yorks*

Student

Blackbrough, C. M. .. .. *Warwicks*
Braithwaite, P. G. .. .. *Beds*
Brewer, A. J. .. .. *Beds*
Gregory, P. J. .. .. *Beds*
Hitchcock, D. F. J. .. .. .. *Suffolk*
Miller, G. R. A. .. .. *Beds*
Pullen, D. W. M. .. .. *Beds*
Scaramanga, D. G. A. .. .. .. *Hants*
Squires, J. W. .. .. *Beds*
Taylor, M. J. .. .. *Beds*

ADMISSIONS (Continued)

Student

Thomas, P. B. .. .. *Devon*
Tomlinson, J. R. .. .. *Beds*
Williams, J. E. M. .. .. *Carms*

TRANSFERS

Fellow

Hodgkinson, B. .. .. *Worcs*
Gedye, I. D. .. .. *Salop*
Gould, C. W. .. .. *Ches*

Member

Akester, D. .. .. *Somerset*
Hobbs, G. R. .. .. *Lancs*
Oliver, G. J. .. .. *Rhodesia*
Pape, K. W. .. .. *Notts*
Patterson, D. E. .. .. *Beds*
Rattray, R. R. .. .. *Warwicks*
Rodger-Brown, D. .. .. *Suffolk*
Sims, D. A. .. .. *Somerset*
Walters, A. J. .. .. *Bucks*
Webster, E. .. .. *Cumberland*

Graduate

Griffin, A. C. .. .. *Glos*
Holme, H. J. .. .. *Cumberland*
Podmore, T. H. .. .. *Ches*
Shearing, J. D. .. .. *Hants*
Spyvee, P. W. .. .. *Lincs*
Stead, P. F. .. .. *Yorks*
Uma, I. O. .. .. *USA*
Vaudin, M. B. A. J. .. .. *London*
Walker, C. C. B. .. .. *London*
Wheelock, R. A. .. .. *Mon*

OBITUARY

The Council announces with deep regret the death of the following members of the Institution:

Daniels, F. W. .. .. .. *Fellow*
Joyce, R. H. .. .. .. *Associate*
Wallace, N. M. .. .. .. *Fellow*

THE INSTITUTION OF AGRICULTURAL ENGINEERS

ANNUAL CONFERENCE 1970

To be held at
The Institution of Mechanical Engineers
1 BIRDCAGE WALK, LONDON SW1
TUESDAY, 12 MAY 1970

CULTIVATIONS

Current economic trends demand continual intensification of every aspect of crop production, not least among these being cultivations. Many radical techniques arising from the availability of greater tractor power and the development in chemical weed control make it difficult for the farmer to choose the best method for his particular situation.
The programme covers both the current research approach as well as a more applied look at some of the modern trends that are now under development.

Conference Convener: N. J. BROWN, Rothamsted Experimental Station

09.30 Assemble for Coffee

10.00 Annual General Meeting of the Institution

11.00 Presidential Address by H. C. G. HENNIKER-WRIGHT, President of the Institution

11.30 Conference opens—Chairman of First Session: H. C. G. HENNIKER-WRIGHT

11.35 **The Influences of Cultivations on Soil Properties** by N. J. BROWN, Rothamsted Experimental Station

12.00 **The Effects of Traffic and Implements on Soil Compaction** by B. D. SOANE, Scottish Station, National Institute of Agricultural Engineering

12.30 Discussion of First Session Papers

13.00 Lunch Interval

14.15 Conference resumes—Chairman of Second Session: J. G. JENKINS, Childerley Estates Ltd

14.20 **The Long Term Effects of Cultivations** by J. R. MOFFATT, Rothamsted Experimental Station

14.45 **Current Cultivation Techniques** by J. K. GRUNDY, National Agricultural Advisory Service

15.15 Discussion of First and Second Session Papers

16.30 Tea and Dispersal

ANNUAL DINNER 1970

To be held at
St Ermin's Hotel
CAXTON STREET, LONDON SW1
TUESDAY, 12 MAY 1970

18.15 Reception

19.00 Dinner

Guest Speaker: J. W. BEITH, Managing Director, Massey-Ferguson (United Kingdom) Ltd

TICKETS

	NON-MEMBERS	MEMBERS (other than Students)	STUDENT MEMBERS
Conference (including lunch and refreshments)	£8 0 0	£5 0 0	£2 0 0
Dinner (including table wines and gratuities)	£5 10 0	£3 10 0	£2 0 0

Early Application for Tickets is advisable

Applications should be accompanied by remittance payable to 'I Agr E', and addressed to the Institution at Penn Place, Rickmansworth, Hertfordshire, WD3 1RE

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