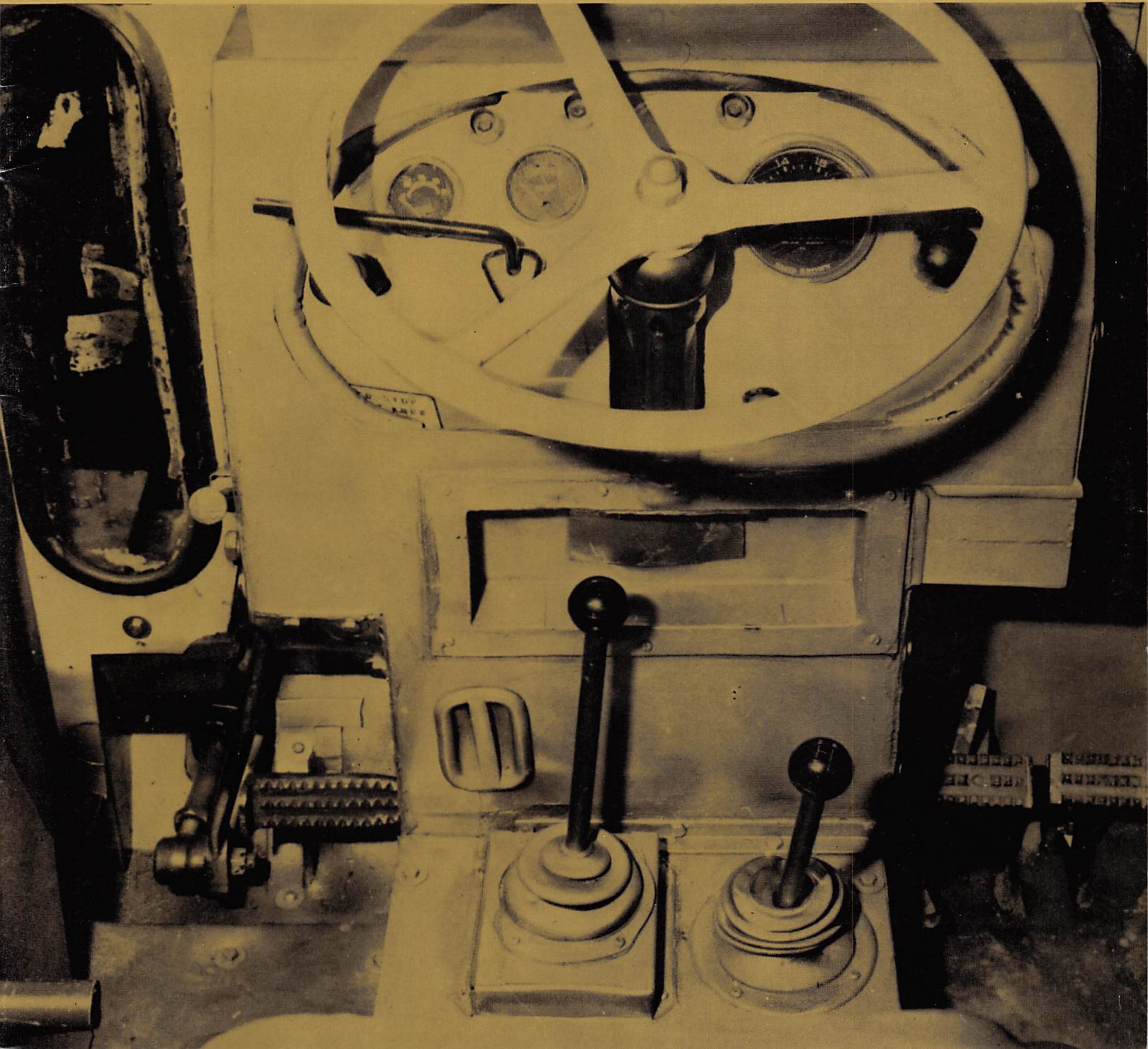
# I AGR E

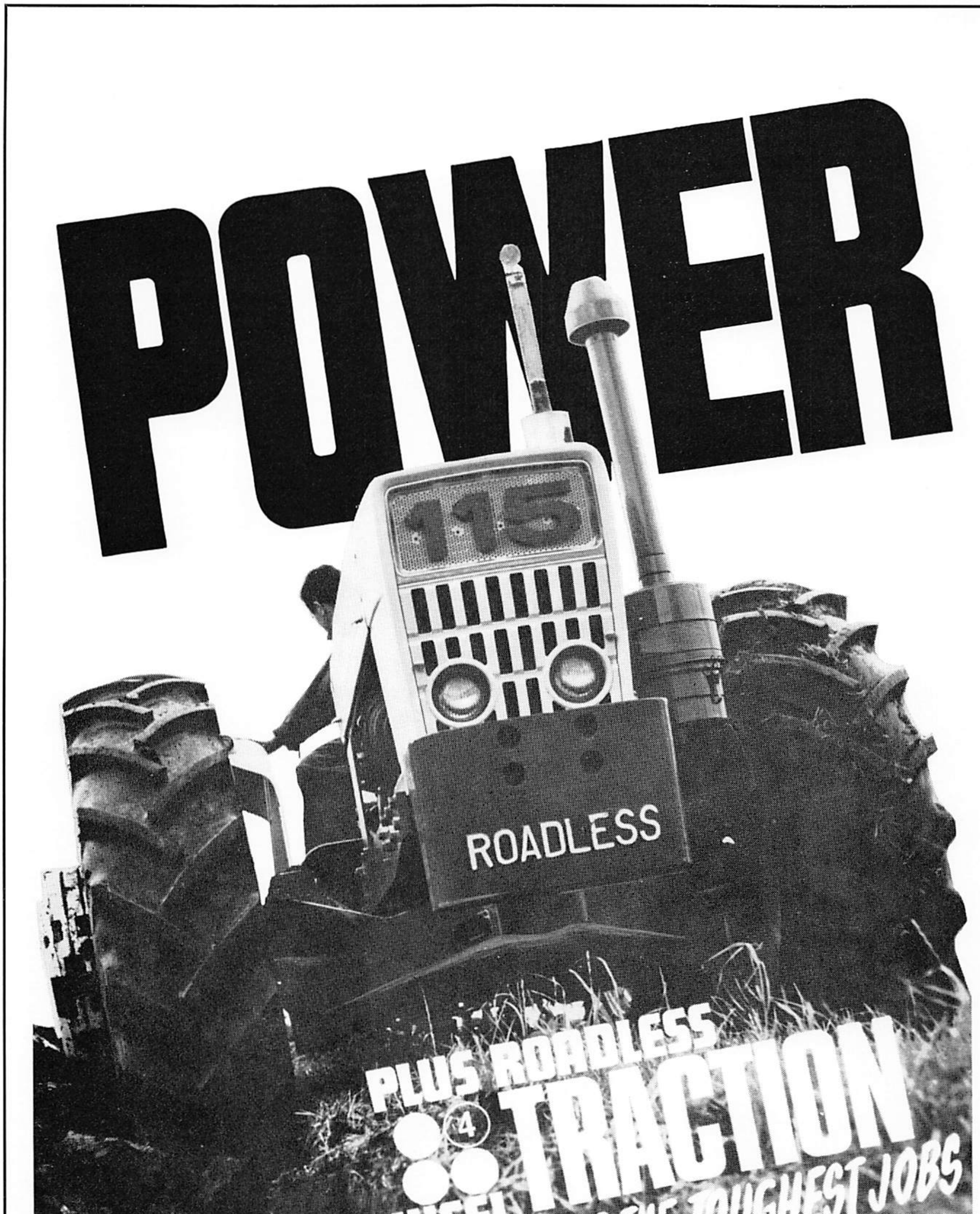
Volume 26
Number 1
Spring 1971

AGRICULTURAL AND ALLIED INDUSTRIAL TRACTORS

A Study of Tractor Noise Control

The Shape of the Farm Tractor

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# JOURNAL

*and Proceedings of*

# THE INSTITUTION of AGRICULTURAL ENGINEERS

**SPRING 1971** **Volume 26** **Number 1**




*The Front Cover illustration is from Figure 16.17 of the paper by J. Matthews and J. D. C. Talamo and is reproduced by courtesy of The Institution of Mechanical Engineers*


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# Marginal Refinement or Major Innovation?

**The 1970 Symposium on Agricultural and Allied Industrial Tractors, jointly sponsored by I Agr E and I Mech E was of great interest, not only for the account of work in progress to provide answers to some of the problems facing tractor and implement designers today, but also for the questions which it posed for the future. The agricultural context was presented in papers by Howard and Fleming-Brown who considered the effect of implement needs on tractor design.**

One main theme is implied in a sentence from Dr Botterill's paper—"Changes in design over the next few years are mostly likely to be predicted by considerations of increased operator comfort and operating convenience". Many of the papers presented acknowledged the importance of the man-machine relationship in the search for greater efficiency and were concerned with improving the current stereotyped trends in tractor design.

These trends were well illustrated by Baker who predicted a continuing increase in the percentage of high power tractors. He considered that the needs in tractor design of developing countries were compatible with those of developed countries, but Kisu, when referring to the trend in Japan away from single axle walking tractors to the riding type of tractor, outlined the special characteristics required to suit local conditions and operators. He maintained that tractors designed for a worldwide market must take account of regional factors, including physiological variations in man, if they are to be acceptable. Height of steps, seating dimensions and adjustment, steering wheel geometry and pedal forces were all considered to require attention.

Some aspects of seating, design of controls, and safety regulations in Germany were outlined by Sonnen. Reference was made during discussion to the problems associated with regulations, including their influence on design and the varying, sometimes conflicting, requirements of different countries. Gannon's paper on braking systems dealt with one aspect of tractor design very much influenced by regulations.

**Delegates were left in no doubt concerning the current importance attached to the problem of noise control, which was the subject of a paper presented by Matthews and Talamo, and reproduced in this *Journal*. The introduction of cabs, particularly of the safety type, has been shown to increase still further the already high incidence of hearing loss encountered by some tractor drivers, due to excessive noise levels. Although some reduction of the noise level may be achieved by modifications to engine design it is proposed that more significant reductions are likely to be achieved by giving attention to acoustic features of the cab or frame cladding. Worthwhile improvements can be achieved by the use of acoustically absorbent linings, substantial floors and bulkheads and resilient mounts. The design of suspended cabs has been studied analytically and experimentally by Hilton. His report showed how tractor operator ride can be improved by isolating the cab from low-frequency ride vibrations. Structure-borne vibration and noise can also be significantly reduced.**

**The second theme of the conference was posed by Reece, whose paper also appears in this *Journal*. He held the view that "... the time is now ripe for a serious attempt to advance tractor design by means of a major leap forward". He maintained that effort put into the further refinement of existing designs was only marginally productive and that significant improvements must come from a radically new concept of tractor design. Such an advance could now be made, based on existing knowledge and competence.**

A number of papers were relevant to this theme, pointing to areas where existing technology had not been utilised in practice. Eyles and Edghill reported progress with hydrostatic transmission, particularly from the point of view of driver control and transmission response. Tests conducted indicated that a hydraulic transmission could be controlled to give safe and effective operation over a wide range of applications.

Cowell and Dwyer each presented papers concerned with implement control. Dwyer was concerned with elucidating the performance of existing control systems while Cowell attempted to set up some signposts for the development of systems which could be used at increased operating speeds. A computer aided technique for the design of components to satisfy specified parameters was presented by Caywood and Basrai. Use of the method was illustrated by reference to the preliminary design of a relief valve when a considerable saving of time and expense was achieved compared with the conventional trial solution. Singh presented details of an approach to the laboratory simulation of field load spectrum which can overcome the difficulties and high cost of testing under actual field conditions. The technique makes use of modern and sophisticated instrumentation.

Increased speed of operation was at the centre of Reece's argument for a new tractor concept since it is the most effective way of utilising the maximum proportion of available engine power when using cultivation equipment In order to achieve increased operating speeds a complete vehicle suspension was required, possibly of a refined nature. In solving this problem many other problems, such as those of operator comfort and implement control, might be alleviated.

**The overall impression of the conference was that the two themes of development and of innovation were linked in many areas—operator efficiency, transmissions, implement control. It was difficult, however, to identify the stimulus which would initiate the commercial materialisation of Reece's vision. The surest foundation for commercial viability appears to be vested in the continued marginal refinement of an existing product. What individual or organisation has the courage and resources to sponsor a major innovation?**

F. M. Inns
B. A. May
*I Agr E Editorial Panel*

# INSTITUTION NOTES

## The Institution and CEI

As reported in *Newsdesk* (page 6) arrangements are now complete for the establishment of the Engineers Registration Board (ERB) under the aegis of the Charter of the Council of Engineering Institutions (CEI).

The Institution has played an active role in this development throughout the past three years. From 1967 to 1970, it had an influential voice in SCNQT (Standing Conference for National Qualification and Title) a consultative group of some forty chartered and non-chartered institutions, called together to advise CEI on acceptable parameters of education, training and experience to be associated with "across-the-board" standards for registration. SCNQT had great success in this but ran into difficulties as to how a composite register should be controlled and operated. So strongly did twenty-three of SCNQT's non-chartered institutions feel about this that they grouped together and formed a new registering company called *Standing Conference for Technician Engineers and Technicians Limited* (*SCTET*). However, the Institution, together with some half a dozen other non-chartered bodies and eight chartered ones, decided against joining SCTET, feeling that CEI itself, being the acknowledged custodian of the engineering profession in the public interest, must be encouraged to make provision under its Charter for a comprehensive system of registration.

This was the background against which, at the 1970 Annual General Meeting, the Institution Council sought and obtained a mandate to enter into direct negotiations to affiliate the Institution to CEI on terms and conditions that the membership could accept. It appeared then, on CEI's own admission, that affiliation might have to be the avenue whereby members of non-chartered institutions could become registered under any system provided by the CEI Charter. Since then, intensive consultations have taken place between CEI and the Institution (in company with other non-chartered bodies) culminating in the recent announcement that the Engineers Registration Board is to be formed. It transpires after all that affiliation to CEI is not the paramount necessity it was earlier thought to be, at least so far as registering technician engineers and engineering technicians is concerned. The Institution may apply to join ERB on the strength of its being a properly constituted engineering body performing a qualifying function in respect of its corporate membership and satisfying the relevant CEI By-laws and ERB Regulations affecting registration of engineers. When the Institution is an ERB member, the agricultural engineer whose name is entered in a section of the register will benefit from the use of the appropriate title and designatory initials. Displayed alongside his qualifying membership grade within the Institution, they will clearly show that his (or her) standard of qualification and experience in agricultural engineering is one that is recognised nationally and will convey this fact to employers, the engineering profession in general and society at large.

It is expected that anyone in the corporate grade of Member who desires to be registered for the title *Technician Engineer CEI*, with the initials *T Eng*(*CEI*), will be able to do so via the Institution soon after the Register is opened. The same will apply to any Technician Associate who wants to become a *Technician CEI*, with the initials *Tech*(*CEI*), although this section of the Register may take a little longer to become operative. Every corporate member and Technician Associate will receive particulars of how he can register as soon as these are available.

All this does not mean that affiliating the Institution to CEI is any the less desirable. A closer association with CEI must be to the benefit of the agricultural engineering community and it will still be diligently pursued. A way has still to be found of registering Fellows (and suitably qualified Members) as chartered engineers. Could Institutional affiliateship of CEI be the key that turns this lock? Nobody yet knows, nor has anybody yet been heard to say that this possibility is ruled out. Happily, CEI has agreed to re-examine the subject of affiliateship as soon as the immediate pressure of setting up the new composite register has eased.

Fellows of the Institution will not be encouraged to register for the title *T Eng*(*CEI*) even though registration for the title *C Eng* is not currently available to them via this Institution. True, a Fellow will not be debarred from applying for *T Eng*(*CEI*) and he would not be refused it. But it is hoped that as many Fellows as possible will help their own cause by remaining for the time being unregistered, thereby throwing into sharp relief the problem that this Institution, among others, will go on striving unremittingly to solve.

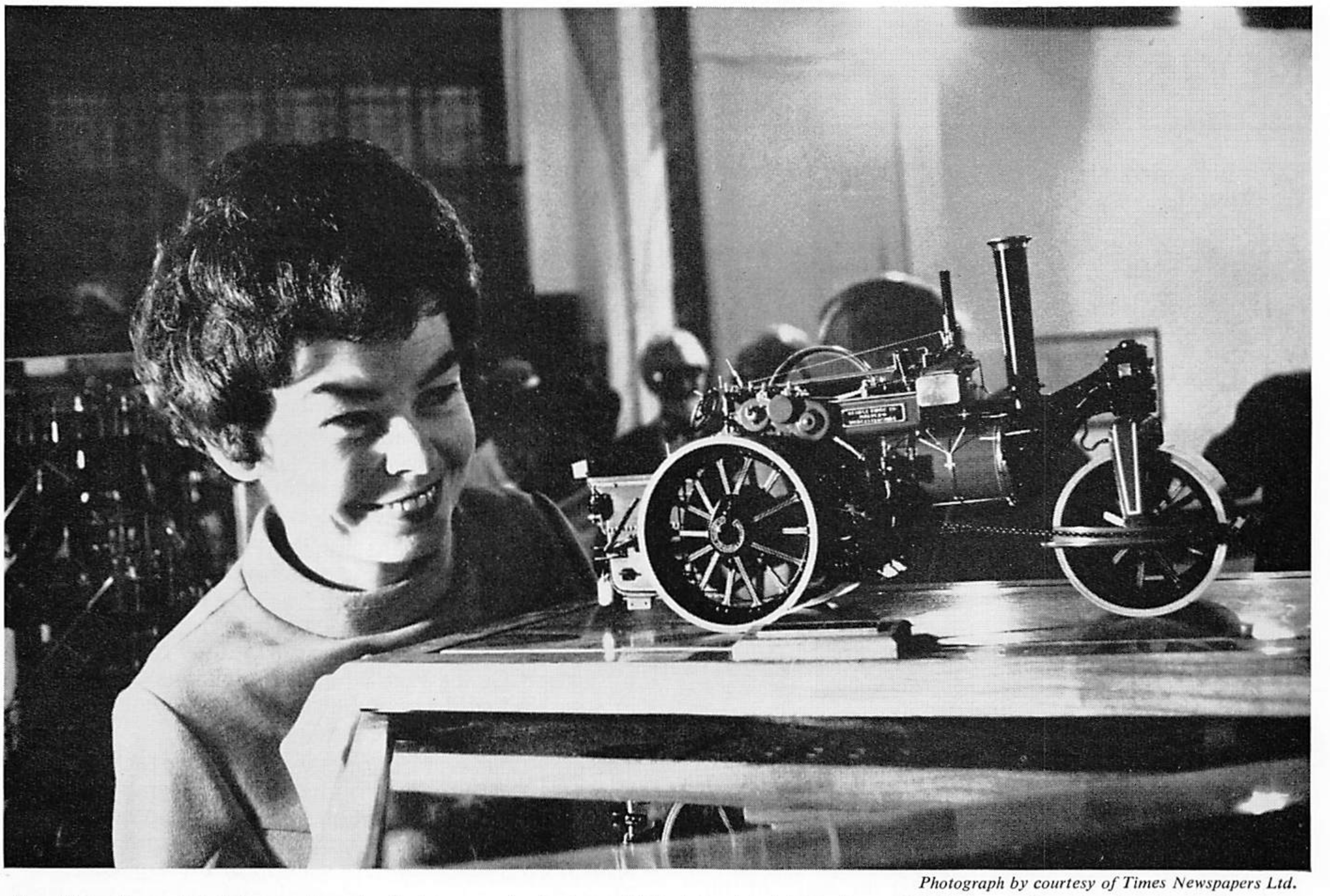
Here is a cheering message for Fellows who consent to a temporary spell of martyrdom! It comes from no less a personage than John Davies, Secretary of State for Trade and Industry. In a House of Commons statement in February he warmly welcomed the establishment by CEI of the new Engineering Registration Board with its provision for a three-part register. He went on to say that he regarded it as important that early steps be taken to ". . . .permit engineers who already have the appropriate qualifications, but are not members of a constituent institution of the Council of Engineering Institutions, to be eligible for registration as chartered engineers, provided that they comply with all the other requirements for this qualification. . . ."

Mr Davies made it clear that, on the basis of the above and certain other provisions, he saw the new proposals as a major step forward for the whole engineering community.

## The Future of the Yearbook

The Institution first published its *Yearbook* in 1955. From a comparatively modest beginning it has blossomed over the ensuing fifteen years to become a useful handbook for the agricultural engineer in the day to day practice of his profession.

Over the years, the *Yearbook* content has become distilled into several clearly identifiable components. This has been most evident in the Index of Members, causing the title of the book to be changed in 1965 to *Yearbook and Membership Directory*. The Membership Index itself was then produced in a colour-tinted supplement. Unfortunately, spiralling costs of printing now cause the *Yearbook* to be



*Photograph by courtesy of Times Newspapers Ltd.*

A smiling Cherry Hinds is seen here beside her award-winning exhibit at the Model Engineer Exhibition in London last December (see below under "She's a Jolly Good Fellow".

unduly expensive to go on producing in its present form. Much of its content already appears in other Institution booklets and pamphlets, notably the *Guide to membership* and the advisory feature entitled *Careers in Agricultural Engineering.* As these will continue to be independently available, it is felt that they should not any longer be reproduced in the *Yearbook.* Other material will be diverted to the *Journal*, which has itself undergone major redevelopment during the past year and is well-suited to absorb such features as the *Subject Index of Papers*, the names of Institution Officers and Standing Committee Members and similar directory information, which is subject to seasonal amendment.

### She's a Jolly Good Fellow

And so say all in the Institution, especially in the West Midlands Branch where they proudly number among their membership a redoubtable lady, Cherry Hinds, who is not content just to be the only lady Fellow in the Institution. She has to be the only woman to go and take the top prize in the Model Engineer Exhibition in London last December, by winning the Duke of Edinburgh Challenge Trophy. Is nothing sacred?

Miss Hinds, director of an agricultural engineering firm near Worcester, began model engineering about ten years ago, purely as a hobby. The model which won her the challenge Trophy is an exact replica ($\frac{1}{16}$th scale), working model of an Aveling and Porter Compound AF-type road roller of the year 1931. It took Miss Hinds three years to prepare the drawings, and to build and finish the model, complete in its glass case. And all done in a workshop at home during weekends and evenings.

The Exhibition Manager, Mr D. J. Laidlaw-Dickson, was heard, through tears, to say that Miss Hinds' win was an exceptional achievement. "This is something that has not happened before," he said, and darkly added "I am sure the men will be careful to see that it does not happen again".

Spoken like a potential President of Men's Lib!

### That Postal Stoppage

The Institution like everybody else, suffered its share of dislocation due to the national postal dispute earlier this year. It was with regret that the organisers of the eagerly-awaited Spring National Meeting, which should have taken place on 30 March, had to call a halt to it. It will take place instead on Thursday 1 July 1971. The entire programme on "Selection and Development of New Products" is being preserved intact, with the same speakers, venue and timing as already announced. Only the date has changed. From the numerous enquiries already received, the event should rate a bumper attendance.

Publication of the *Journal* has also been affected. Despatch of the Winter 1970/71 number was delayed several weeks and this present issue also appears a good deal later than usual. The publishers greatly regret this inconvenience but everything is now back on course. Given a normal situation, the Summer issue of the *Journal* will come out in August.

Members of the Institution were doubtless as heavy-hearted at not being able to pay their subscriptions throught the post as the Institution Secretary was at not being able to pay the Institution's bills! Thankfully, annual subscriptions have since been received at a great rate but there are still some members who have not yet been fired by this resergent spirit.

Perhaps this little reminder will do the trick. □

# NEWSDESK

## Engineers Registration Board Receives Go-Ahead

Mr. John Davies, Secretary of State for Trade and Industry, speaking in the House of Commons on 15 February, warmly welcomed the new composite registration system as a major step forward for the whole of the engineering community.

Very much as expected, the Privy Council has approved the application made by the Council of Engineering Institutions (CEI) for amendment of its Royal Charter and Bylaws to make possible the setting up of a composite register and an Engineers Registration Board, to operate under the aegis of the Charter.

Eligibility for membership of the Engineers Registration Board (ERB) and for registration of individuals, is clearly set out in the Bylaws which provide a suitable and rational arrangement for ensuring that the qualifications of all those registering as chartered engineers, technician engineers and engineering technicians, can be properly recognised as such by industry throughout the country and elsewhere.

Admissions to the register and overall administration will be regulated by specialist committees of the three autonomous sections. The work of these sections will be channelled to the main registration board through a co-ordinating committee made up of sectional representatives.

The title of *chartered engineer* and its abbreviated designatory initials *C Eng* are already well established and protected. Now the abbreviated designation *T Eng* (*CEI*) will become available to individual members of qualifying engineering bodies within membership of ERB, denoting that the qualified technician engineer holds an academic qualification not lower than that exemplified by a Higher National Certificate or a City and Guilds Full Technological Certificate in approved subjects, as well as meeting further requirements as to minimum standards of training and experience.

Engineering technicians admitted to the technician section of the register and awarded the abbreviated designation *Tech* (*CEI*) will be those possessing an academic qualification of a standard not lower than that exemplfied by an Ordinary National Certificate or a City and Guilds Part 2 Final Technicians Certificate in approved subjects and also satisfying minimum training and experience requirements.

The new titles and designatory initials for technician engineers and engineering technicians were arrived at only after wide consultation and with the assurance that they could be used only by those whose names appear on the appropriate section of the register. Thus, they are legally protected against improper use or "passing-off" by unauthorised persons. The table below summarizes the titles, designatory letters, eligibility and qualification levels which are detailed in the amended CEI Bylaws.

CEI is shortly expected to announce the names of those institutions and societies who will be Founder Members of the Engineers Registration Board. As well as including the fifteen chartered institutions who may currently register their corporate members as chartered engineers, the Board will almost certainly include the names of several non-chartered institutions who have been actively helping CEI during the past year or so to establish the new sections of the composite register.

### ENGINEERS REGISTRATION BOARD

| TITLES | LETTERS | ELIGIBILITY | LEVEL OF QUALIFICATION |
|---|---|---|---|
| CHARTERED ENGINEER | C Eng | (a) must be a corporate member of one of the Constituent Members of CEI; (b) be qualified in accordance with CEI By-laws 36 to 39. | Degree or equivalent in engineering or accepted related subjects plus training and experience |
| TECHNICIAN ENGINEER CEI | T Eng (CEI) | (a) must be a member of an Institution or society which is itself a member of the ERB; (b) must be qualified in accordance with CEI By-law 41. | Not lower than that exemplified by a Higher National Certificate or a City and Guilds Full Technological Certificate in accepted subjects plus training and experience |
| ENGINEERING TECHNICIAN CEI | Tech (CEI) | (a) must be a member of an Instituion or Society which is itself a member of the ERB; (b) must be qualified in accordance with CEI By-law 42. | Not lower than that exemplified by an Ordinary National Certificate or a City and Guilds Part II Final Technicians Certificate in accepted subjects plus training and experience |

At the time of going to press with this issue of *Newsdesk*, the names of the non-chartered Founder Member Institutions have not been announced. The signs are however that the agricultural engineering community will not be disappointed.

### Exit SCNQT

The Standing Conference for National Qualification and Title (SCNQT) was set up in 1967. By the close of 1970, its task over, the Standing Conference decided to end its existence and it was therefore dissolved. Part of the uniqueness of SCNQT however was that it made possible an exchange of ideas and opinions among a wide range of engineering institutions and societies. To continue this facility it was agreed by a large majority to form an Engineers Forum which would be an informal association open to all organizations having an interest in engineering in its broadest sense. The new body will not involve itself with titles and registration, which were the principal concern of SCNQT, but may usefully discuss such subjects as educational policy, training, the future of the Training Boards and matters of national policy affecting engineers. The Steering Committee, formed to develop terms of reference for the Engineers Forum, is as follows:-

J. K. Bennett, Institution of Agricultural Engineers
B. G. Fish, Institute of Quarrying
H. W. Payne, Society of Licensed Aircraft Engineers and Technologists
K. H. Platt, Institution of Mechanical Engineers
A. G. Stone, Institution of Plant Engineers

### The National Diploma in Agricultural Engineering

In June 1968 the Examination Board in Agricultural Engineering gave notice that the new pattern of courses under the Joint Committee for National Awards in Agricultural Subjects would eventually lead to the phasing-out of the examination for the National Diploma in Agricultural Engineering (ND Agr E), which would be superseded by alternative examinations.

The Examination Board is now satisfied that alternative courses and examinations of equivalent level will be available to meet the needs of all candidates and announces its decision to hold the last full examination for the ND Agr E in 1974; provision will be made for re-sits in 1975.

The alternative examinations which the Board has in mind include those listed below. Other courses of a similar standard may also come into being in addition to those mentioned. In each case it is expected that, subject to the provisos mentioned, the courses will be accepted as equivalent to a Part IIA qualification under the membership regulations of the Institution of Agricultural Engineers, leading to Graduate membership and eventually to corporate membership of the Institution in the Member grade. Institution members qualified in this way are also expected to be eligible for registration as *Technician Engineers CEI* with the designation *T Eng* (*CEI*).

For the engineering approach to the ND Agr E:-

i City and Guilds Examination 465 (Stage 3) provided that six subjects are passed at credit level, normally in not more than two consecutive years and normally with at least four subjects taken in the first year;
ii The College Diploma in Agricultural Engineering of the West of Scotland Agricultural College.

For the agricultural approach to the ND Agr E:-

i A one-year post-HND endorsement course in Agricultural Mechanization, approved by the Joint Committee for National Awards in Agricultural Subjects, following an HND in Agriculture or Horticulture;
ii The College Diploma in Agricultural Engineering of the West of Scotland Agricultural College.

The Examination Board and the Institution of Agricultural Engineers retain their right to exclusive use of the title "National Diploma in Agricultural Engineering" and its abbreviation "ND Agr E" in order to safeguard the interests of those who already hold the Diploma. No alternative uses of the title are envisaged at the present time.

### Less Government Aid for Information, Advice and Development

Universal bewilderment and disappointment. This seems to sum up the widespread reaction throughout industry at the recent Ministry of Agriculture decision to withdraw support for the testing of agricultural machines which are in commercial production–an official service formally provided by the NIAE. In paragraph 17 of the White Paper (Command 4564) *Proposed Changes in the Work of the Ministry of Agriculture, Fisheries and Food* the Minister, Mr. Prior, wound up the almost lifeless testing scheme which once showed such promise with these few words:- "The scheme for testing agricultural machines currently on the market is to be ended. It was introduced to help farmers choose the most appropriate machine for their particular requirements and to help manufacturers improve their products. Advice and information exists from a variety of commercial sources to assist farmers in their choice and ordinary commercial pressures should ensure that manufacturers maintain a high standard of product."

Another change in Government policy announced at the same time is concerned with proposals to cut the Ministry's advisory services. The "Blue Book" concerning the new Agricultural Development and Advisory Service (ADAS) includes two paragraphs of importance to agricultural engineers, as follows:-

Mechanization Group

58 Mechanization advisers are based mainly in counties. Apart from advice to other disciplines these advisers give specialist advice on the whole range of mechanization in agriculture and horticulture, particularly on mechanization systems. The group has developed specializations e.g. in glasshouse heating, livestock mechanization and vegetable production and harvesting. The group as a whole is in considerable demand for advice particularly where heavy investment in machinery is involved.

59 This is a field in which the farmer ought to become much more self-reliant. The trade itself is highly competitive, and farmers should look to it to provide such advice as they need on the more routine matters concerned with the operation of equipment, and the trade should provide it. General advisers in their wider role will deal with most problems which remain. Some specialist engineers will still be required but only to the extent of a small group at each regional centre to do development work and to give specialist advice on investment in mechanization systems.

It is expected that a full review of functions and needs will be made before detailed decisions are taken. There is room for differences of opinion about the value of various kinds of testing, information and advisory services carried out on behalf of the consumers and about who should pay for them; but there can be little doubt about the value of the services that are to be withdrawn or curtailed.

### More About Metric

The Metrication Board announced recently that work on the Metric Based Price Schedule for Steel Sheet Products is well advanced and a pamphlet summarizing British Steel Corporation proposals is expected at any time now.

The Board also announced that a wide range of metric steel machine screws will be readily available very shortly. The range is set out in full in a *Selected list of preferred metric sizes of steel machine screws.* The list was prepared by the Working Party on Fasteners which was convened jointly with the Metrication Board and the Confederation of British Industry. Users and designers would be well advised to make their first choice of metric steel machine screws from the *select list.* Further sizes will be added in accordance with user demand.

Wide ranges of metric black and precision bolts and screws will also be available shortly to meet the demands of users. The ranges are set out in *Select lists of first and second choice preferred metric sizes of precision and black bolts and screws* published by the Metrication Board. The information will be included in the British Bolt, Nut, Screw and Rivet Federation's publication "Data and Information on ISO Metric Bolts and Nuts; High Tensile BS 3692 and Black to BS 4190", available from the Federation at 69 Harborne Road, Edgbaston, Birmingham B15 3AN.

### Farm Buildings Scholarship

A Farm Buildings Scholarship is to be awarded by the Cruden Foundation for work at the Scottish Farm Buildings Investigation Unit on the rationalization of farm building techniques. The Scottish Farm Buildings Investigation Unit at Aberdeen provides facilities for theoretical, workshop and field development work on farm buildings, while assistance in related spheres is available from the Aberdeen School of Agriculture.

The Scholarship is open to applications from graduates in architecture, building science, building surveying or civil engineering and normally will be tenable for three years. Further particulars may be obtained from the Secretary, The North of Scotland College of Agriculture, School of Agriculture, 581 King Street, Aberdeen AB9 1UD (Tel. Aberdeen 40291).

### Good and Bad News

The good news is that fatal accidents on farms during 1970 were ten fewer than in the previous year. The bad news is the tragic fact that of the 105 fatal accidents on farms in 1970 there were more involving children. This emphasizes the need for better supervision of children and a greater awareness of the dangers which are present for them on the farm. 13 children were killed by farm machinery as against 7 in 1969 and 5 in 1968.

The overturning tractor was still the main cause of fatalities. The number of deaths from this cause was 26, six fewer than in the previous year. It may be significant that this reduction occurred during the year in which the provisions of the Agricultural (Tractor Cabs) Regulations 1967 became fully operative. One must hope for an even more significant reduction in deaths from this cause in 1971 which will be the first full year in which the new regulations will have effect.

### The Industrial Relations Bill and the Professional Engineer

The letter from Mr Theo Sherwen in *Viewpoint* (see page 44) echos the anxiety felt by many about the position of the professional engineer in arrangements for collective bargaining between employers and workers, if and when the Industrial Relations Bill becomes law.

According to a report by *Times* correspondent, Dennis Dwyer, in January, the Council of Engineering Institutions is seeking changes to the Bill so that when chartered engineers are involved in collective bargaining they have separate representation to their satisfaction in any "agency shop agreement". Provision is also to be sought within the Bill to enable the profession to be represented so that it can establish its requirements to the appropriate statutory agencies. CEI also feel that there should be statutory provision for the category of worker, as exemplified by a chartered engineer, who has special obligations in the public interest which are material to his employment.

Under the Bill, an "agency shop agreement" is an arrangement between an employer and one or more trades unions whereby the employer agrees that workers must either be or become a member of a trade union or agree to pay contributions to the trade union, in lieu of membership, or to pay equivalent contributions to a charity. Another clause gives every worker the right to belong to a trade union and the right not to belong. Chartered engineers are employed in many different industries and in some cases they are already represented by trade unions, but many are not trade unionists. □

## Dates for your Diary

I AGR E POSTPONED SPRING NATIONAL MEETING

**SELECTION AND DEVELOPMENT OF NEW PRODUCTS**

at the National College of Agricultural Engineering, Silsoe, Bedford
on Thursday 1 July, 1971

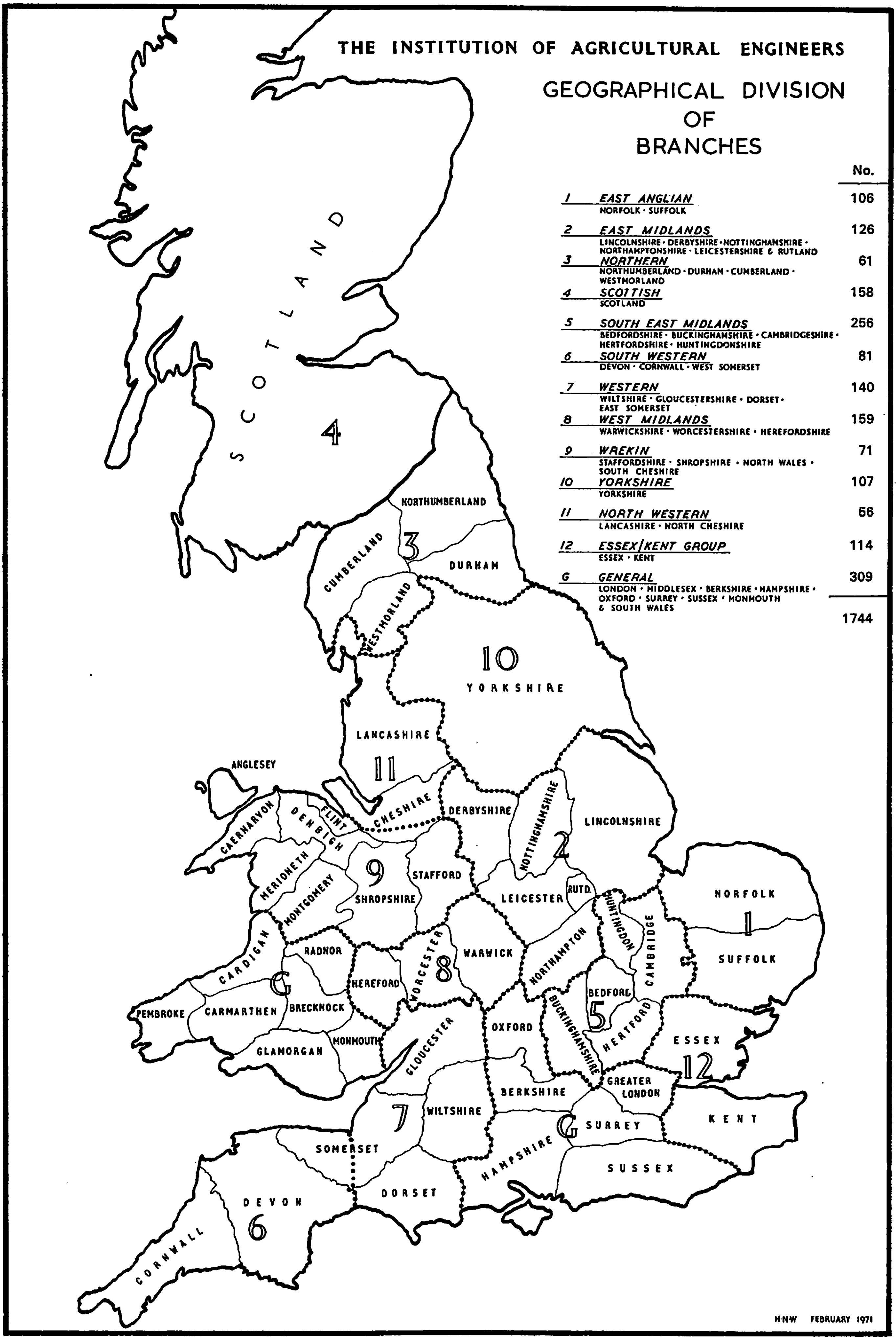
*For full details turn to page 13 of this issue of the Journal*

I AGR E AUTUMN NATIONAL MEETING

**ENGINEERING FOR MILK PRODUCTION**

at The University of Reading, Reading, Berkshire
on Thursday 30 September, 1971

*Full details will be announced shortly*


THE INSTITUTION OF AGRICULTURAL ENGINEERS
GEOGRAPHICAL DIVISION OF BRANCHES
No.
1 EAST ANGLIAN 106
NORFOLK · SUFFOLK
2 EAST MIDLANDS 126
LINCOLNSHIRE · DERBYSHIRE · NOTTINGHAMSHIRE · NORTHAMPTONSHIRE · LEICESTERSHIRE & RUTLAND
3 NORTHERN 61
NORTHUMBERLAND · DURHAM · CUMBERLAND · WESTMORLAND
4 SCOTTISH 158
SCOTLAND
5 SOUTH EAST MIDLANDS 256
BEDFORDSHIRE · BUCKINGHAMSHIRE · CAMBRIDGESHIRE · HERTFORDSHIRE · HUNTINGDONSHIRE
6 SOUTH WESTERN 81
DEVON · CORNWALL · WEST SOMERSET
7 WESTERN 140
WILTSHIRE · GLOUCESTERSHIRE · DORSET · EAST SOMERSET
8 WEST MIDLANDS 159
WARWICKSHIRE · WORCESTERSHIRE · HEREFORDSHIRE
9 WREKIN 71
STAFFORDSHIRE · SHROPSHIRE · NORTH WALES · SOUTH CHESHIRE
10 YORKSHIRE 107
YORKSHIRE
11 NORTH WESTERN 56
LANCASHIRE · NORTH CHESHIRE
12 ESSEX/KENT GROUP 114
ESSEX · KENT
G GENERAL 309
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BERKSHIRE
WILTSHIRE
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SOMERSET
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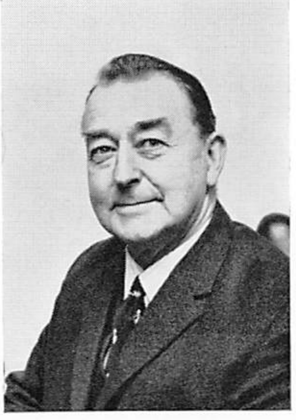
# NEWS FROM BRANCHES

### A New Branch in the North West



**Tom Dewes becomes first Chairman of the new North Western Branch**

The Institution took a major step forward in January, when the Council gave formal approval to a new Branch being formed in Lancashire and North Cheshire. Known as the North Western Branch, it brings more than fifty members with widely varied interests into closer touch with the Institution and with each other, via the regional activity which full Branch status alone can make possible.

There are now ten full Branches of the Institution in the UK. Their disposition is shown on the map opposite.

Efforts to promote the Institution's development in the north-west have been evident for many years, thanks not only to a nucleus of untiring members in Lancs and Cheshire but also the official sponsorship and unflagging support of the neighbouring Yorkshire Branch. Members west of the Pennines were for a long time "attached" administratively to Yorkshire and in 1967 it became possible to form a Merseyside Sub-Branch. This laid the effective foundations for this latest move and it was as a result of a recommendation from the Yorkshire Branch to Council that the final go-ahead was given.

The North Western Branch held its first General Meeting at Chorley, Lancs on 25 March. Among those present were the National Secretary, Jon Bennett and his Assistant Secretary, Harold Weavers. Mr Bennett said that the birth of a new Branch would bring pleasure and satisfaction to the Institution's entire membership and could not fail to be a great tonic to agricultural engineering throughout the north-west.

Fittingly, the Chairman of the former Merseyside Sub-Branch, Mr T. D. Dewes, was elected Founder Chairman of the new Branch. A fellow of the Institution, Yorkshire-born Tom Dewes is a MAFF Metrication Adviser at Preston. His special interests include grain drying and cooling, and hay drying. He has not always worked in the north. Mr Dewes spent some sixteen years in Kent where he earned the special respect of the local NFU for his practical approach and lively enthusiasm.

"Now that we are a separate Branch" said Mr Dewes at the Chorley meeting, "we are on our own and must redouble our efforts. I have no doubt about the ability to meet and exceed the membership target recruitment figure recently given to us by the President. We intend to play a flourishing part for the benefit of our members in this region and the Institution at large".

### West Midlands Branch

"New service disciplines will have to be accepted by farmers, tractor drivers and agricultural dealers repair staffs now that alternators are replacing dynamos on tractors and agricultural machines in ever increasing quantities". A well-attended meeting of the Branch was told this at Kenilworth in November. The speaker, Mr Roger Bater, of Joseph Lucas Limited, outlined the advantages of replacing the conventional dynamo with an alternator. Much higher outputs of electricity were now required (particularly at low engine speeds) to provide for the greatly increased demands created by heater plugs, electric wipers, starters, lights and in some cases even radios and cigarette lighters on tractors and farm machines. To provide these by increasing dynamo size and output would make the dynamo very large, heavy and costly and its associated separate control box and equipment an embarrassment for agricultural machinery designers.

The alternator, which was now highly developed, giving much more output, would produce current at idling speeds and was much smaller and lighter, could be mass-produced and there was no need for a separate voltage control box. This function was now cleverly miniaturized (like a transistor radio circuit) into a system of tiny semi-conductor diodes, and this whole solid-state package was built into the end of the alternator unit itself.

The speaker forecast the increasing popularity of the alternator on farm machines and road vehicles, and said that dynamos would become rapidly dearer as demand fell and production costs had to be spread over a smaller number of units required.

The Branch held its next meeting at Leamington in January. Director of Studies at the Harper-Adams Agricultural College, Mr R. G. Mortimer, spoke about mechanization of livestock feeding. Emphasizing the economic pressures put on farmers through the labour shortage and the high capital needed to implement mechanized feeding, Mr Mortimer made several references to the American farming industry. "Farmers should not rush blindly into mechanization and spend thousands of pounds only to be disappointed. To obtain the best out of expensive and refined equipment, the best quality feed stuffs should be used. Concentrates are ideally suited. The high capital outlay can be more easily justified with arable machinery than livestock mechanization," Mr Mortimer said. Mechanization had been forced on the American Mid-West farmer because of the lack of labour. Many farms were run just by families, which made machinery a vital part of the agricultural scene. Tower silos were widely used on medium sized farms with 150 cows in the USA and the acute shortage of labour had led to production of small tower and auger feed systems. "Over capitalization on this type of equipment can be a problem ," Mr Mortimer said. "A farmer in Lincolnshire invested so much capital in tower silos, that he did not leave himself enough to buy cows."

Speaking on feeding techniques in general, Mr Mortimer said that machines should be able to handle grass in mid-May and conserve it to get the optimum digestibility and yield, as well as get the job done quickly. The range of appliances available was covered by Mr Mortimer, saying that forage boxes were preferable in his view to augers, as the hazard of cut tongues was then eliminated. "The uniform filling of towers is very important; feeders which throw silage to one side of the tower can cause it to collapse unless there is some sort of spreader," he said.

Turning to the possiblility of using some American feed crops in Britain, Mr Mortimer ruled out the possibility of sorghums, because of the climatic problems Britain would pose. But maize, which was a marginal crop in the Midlands, was already being grown very successfully in the south and east of the country. "Whole crop oats have the greatest potential in this country," he said, "being sown in September, with a July harvest and undersowing in Autumn."

The Branch went to the National Agricultural Centre at Stoneleigh for its next meeting in February. "98% of all sugar beet in the UK is now harvested mechanically, and 66% of the crop is planted with monogerm seed," said the speaker, Mr G. L. Maughan of the National Institute of Agricultural Engineering and currently seconded to the staff of the British Sugar Corporation. He was addressing a meeting on "Recent Developments in the Cultivation and Mechanization of Sugar Beet." Mr Maughan added that "monogerm" seed accounted for 95% of the total crop in Sweden, 65% in Finland, but in Holland and Germany less than 20%. Referring to seed spacing he said that in 1966 over 40% of the precision-drilled crop was planted less than 2 in. apart, but in 1970 29% was widely spaced at 5 in. and over! 30% of all sugar beet was "planted to a stand" in Belgium, Austria and the UK. Row-widths of 18 in. or 20 in, (45 or 50 cm.) were common on the Continent, but 15¾ in. rows in Germany had presented tyre problems. Wide machines could travel more slowly and give lower top losses. Top saving mechanisms were only worthwhile if the tops could be fully utilized, as they tended to slow down the rate of work. Small harvesters were adequate if the campaign season was a long one and large multi-row machines were only justified if time was vital, as they delivered a high percentage of green leaf and stem material which contains oxalic acid in the form of "top tare" causing factory processing problems.

With reference to the Common Market, Mr Maughan said that France was over-producing by about 4% and there was need for all countries to review acreage to combat over-production. One-third of sugar for the UK was home-produced from beet and the other two-thirds was from West Indies area sugar cane. Complete harvesters were still the most popular machines in Britain with tanker machines taking over from direct loaders. The swing to self-propulsion was steady but not rapid. "It is to be hoped" concluded Mr Maughan "that manufacturers of towed machines will give serious consideration to the incorporation of some sort of row-alignment device. Three-row harvesters are expected to become more widely used in this country." □

### OBITUARY

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

| | |
|---|---|
| Bowden, C. | *Graduate* |
| Hoggarth, T. | *Member* |
| Jackson, R. A. | *Fellow* |
| Snook, F. J. | *Associate* |

## Institution Activities

**The following Institution officers will gladly keep you informed of sessional activities in their areas.**

**NATIONAL ACTIVITIES**
*Asst. Secretary (Publicity):*
H. N. WEAVERS
The Institution of Agricultural Engineers
Penn Place, Rickmansworth, Herts.

**EAST ANGLIA**
*Branch Hon. Secretary:*
J. B. MOTT, MI Agr E
County Education Office, County Hall
Norwich, NOR 49A

**EAST MIDLANDS**
*Branch Hon. Secretary:*
R. D. S. BARBER, BSc, ND Agr E, MI Agr E
The Farm Institute, Caythorpe Court
Nr. Grantham, Lincs.

**ESSEX/KENT GROUP**
*Group Hon. Secretary:*
K. A. McLEAN, NDA, CDA, CDAE, ND Agr E, MI Agr E, Min of AFF
Beeches Road, Chelmsford, Essex

**NORTHERN**
*Branch Hon. Secretary.*
R. COWAN, MI Agr E
Northumberland College of Agriculture
Kirkley Hall, Ponteland, Newcastle upon Tyne

**NORTH WESTERN**
*Branch Hon. Secretary:*
F. J. HEATHCOTE, AI Agr E
Mozart House, Spendmore Lane, Coppull,
Nr Chorley, Lancs.

**SCOTTISH**
*Branch Hon. Secretary:*
G. C. KERR, AI Agr E
Thirlestane, Burnhead Road
Blairgowrie, Perth

**SOUTH EAST MIDLANDS**
*Branch Hon. Secretary:*
G. SPOOR, BSc, (Agric), MSc (Agr Eng), MI Agr E
National College of Agricultural Engineering
Silsoe, Beds.

**SOUTH WESTERN**
*Branch Hon. Secretary:*
C. R. CLARKE, MI Agr E
15 Spurway Road, Hay Park
Tiverton, Devon

**WESTERN**
*Branch Hon. Secretary:*
H. CATLING, ND Agr E, MI Agr E
Engineering Department,
Royal Agricultural College
Cirencester, Glos.

**WEST MIDLANDS**
*Branch Hon. Secretary:*
M. J. BOWYER, C Eng, MI Agr E
9 Lyng Close, Mount Nod, Coventry, CV5 7JZ

**WREKIN**
*Sub-Branch Hon. Secretary:*
J. SARSFIELD, ND Agr E
Staffordshire College of Agriculture
Rodbaston, Penkridge, Stafford.

**YORKSHIRE**
*Branch Hon. Secretary:*
J. MAUGHAN, BSc, MSc, MI Agr E
48 The Hollows, Bessacarr
Doncaster, Yorks.

THE INSTITUTION OF AGRICULTURAL ENGINEERS

# POSTPONED SPRING NATIONAL MEETING 1971

This meeting, originally planned to take place on 30 March and then postponed owing to the postal stoppage will be held at
The National College of Agricultural Engineering
SILSOE, BEDFORD on
THURSDAY, 1 JULY 1971

## SELECTION AND DEVELOPMENT OF NEW PRODUCTS

The selection of a new product involves management decisions and approaches which are hardly ever discussed.
This is an area in fact where many firms are reticent on how they arrive at a new product and this Meeting will seek to show how the management of some companies with widely varying structures and interests tackle this problem and it is hoped that case histories of certain products will illustrate the process.

Programme Convener and Chairman: T. SHERWEN, C Eng, FI Mech E, FI Agr E, MSAE, Past President of the Institution

PROGRAMME

10.30 Assemble for Coffee

11.00 Introduction by H. C. G. HENNIKER-WRIGHT, FI Agr E, Mem ASAE, Immediate Past President of the Institution

11.15 Paper 1
**Management Control of Design Research and Development** by H. E. ASHFIELD, C Eng, FI Mech E, FI Agr E, Technical Director, David Brown Tractors Limited, Meltham, Huddersfield, Yorks.

12.00 Paper 2
**Finding and Exploiting New Projects for a Small Company** by J. H. W. WILDER, OBE, BA, FI Agr E, Managing Director, John Wilder (Engineering) Limited, Wallingford, Berks.

12.45 Luncheon Interval

14.00 Paper 3
**Product Planning and Development in a Specialised Company** by J. V. FOX, FI Agr E, Managing Director, Bomford & Evershed Limited, Evesham, Worcs.

14.45 Paper 4
**Necessity is Still the Mother of Invention** by W. T. A. RUNDLE, FI Agr E, Managing Director, Wright Rain Limited, Ringwood, Hants.

15.30 **Open Forum:**
Questions and Discussion on the four Papers

16.30 Tea and Dispersal

**TICKETS**

| | NON-MEMBERS | MEMBERS (other than Students) | STUDENT MEMBERS |
|---|---|---|---|
| Inclusive of lunch and refreshments | £8·00 | £5·00 | £3·00 |

Advance copies of the papers will be forwarded with tickets a few days before the Meeting

**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

# PUBLICATIONS

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

**An Air Jet Feeder for Cotton Gin Bale Presses**—by Roy V. Baker

This report deals with tests conducted on an air jet lint feeder at the South Plains Cotton Ginning Research Laboratory, Lubbock, Texas, during the 1968 and 1969 ginning seasons. The author is Agricultural Engineer with the Agricultural Research Service, US Department of Agriculture, South Plains Cotton Ginning Research Laboratory, Lubbock, Texas.

**Annual Report of the Swedish Institute of Agricultural Engineering 1969/70**

Published as Bulletin No. 337, an English translation of the Report is available. A detailed account is given of the Institute's research programme covering such aspects as mechanized haymaking, silage making, preservation and storage of grain, handling of concentrates, harvesting and handling of potatoes, manure, gas and ventilation, the handling of liquid manure, transport, the use of electricity, soil management and tractor ergonomics.

The above Bulletin and other Institute publications can be ordered direct from Jordbrukstekniska Institutet, 750 07 Uppsala 7, Sweden.

**BGMA Buyers' Guide**—by The British Gear Manufacturers' Association

The Association numbers amongst its members principal British manufacturers of machine cut gears, enclosed gear drives, and other power transmission equipment. The guide lists the names and addresses of member associations of BGMA and also gives schedules of the principal types of gears and gear units in general use and the full range of products. Enquiries about the 1970 edition of the guide should be addressed to The British Gear Manufacturers' Association, PO Box 121, 301 Glossop Road, Sheffield, S10 2HN.

**Comparison of Stanchion Barn and Slotted Loose Housing for Young Bulls**—by Anders Nygaard and Even Haugland

The above is published as Scientific Report No. 25 (Volume 49 1970) of the Agricultural College of Norway.

**Curing Burley Tobacco in Plastic-Covered Structures**—by Elmo E. Yoder and Wiley H. Henson, Jr

Approved for publication by the Director of the Kentucky Agricultural Experiment Station, the paper describes studies to evaluate temporary structures covered with polyethylene film for air-curing stalk-cut burley tobacco. The authors are agricultural engineers with the US Department of Agriculture, Agricultural Research Service (Agricultural Engineering Research Division). Enquiries should be addressed to the US Department of Agriculture, Agricultural Research Service, Beltsville, Maryland 20705.

**Current Agricultural Engineering Research and Development Projects in Canada 1970**

Published as Supplement No. 3 (May 1970) by the Engineering Research and Development in Agriculture (ERDA), Ottawa, the Supplement contains a list of agricultural engineering research and development projects carried out across Canada in 1970. It is the result of a recommendation of the Canada Committee on Agricultural Engineering and has been compiled from information obtained from university, provincial and federal establishments as well as utilities working in this field.

Enquiries should be addressed to Department of Agricultural Engineering, The University of British Columbia, Vancouver 8, B.C.

**Emergency Measures in Case of Power Failure**—by Sixten Sorlin

This paper appears as Bulletin No. 336 from The Swedish Institute of Agricultural Engineering, Uppsala, Sweden, and is concerned with suggestions to ensure water supply, milking, feeding and lighting, etc. which may replace the use of electric power in emergencies arising from hurricanes and heavy falls of snow. The author discusses how to calculate the capacity which a stand-by generator must have for farm electrical equipment.

**Engineering Education in the Region**—by the London and Home Counties Regional Advisory Council for Technological Education

An entirely revised and extended edition of the Council's booklet has recently been published, containing information on all levels of courses in engineering offered at colleges in the London and Home Counties region, from craft to post graduate. Details are included of courses with notes on the duration, patterns of study and entry requirements: first degrees at all universities in the region; CNAA degrees; post graduate degrees at polytechnics; courses for the CEI and other professional examinations; National Certificates and Diplomas; CGLI certificates and college certificates and diplomas.

The booklet is a companion volume to the Council's other booklets 'Science Education in the Region' and 'Education for Business and Management in the Region'. Copies of all these booklets (price 40p post free) may be obtained from the Regional Advisory Council at Tavistock House South, Tavistock Square, London WC1H 9LR.

**An Evaluation of the Performance of Two Gin Saw Tooth Designs**—by W. D. Mayfield and O. L. McCaskill.

The authors are research agricultural engineers at the Cotton Ginning Research Laboratory, Stoneville, Miss. The paper describes experiments comparing the performance of a newly-designed gin saw with that of the standard 12 and 16 in. diameter saws used in the cotton ginning industry.

Enquiries should be addressed to the US Department of Agriculture, Agricultural Research Service, Beltsville, Maryland 20705.

**Experiments with Housing for Dry Sows**—by Anders Nygaard, Dag Aulstad, Arvid Lyso, Hans Kraggerud and Nils Standal

Published as Scientific Report No. 31 (Volume 49 1970) of the Agricultural College of Norway, the Report makes a comparison between different types of housing for dry sows with special reference to production, workload, cleanliness and sow behaviour under various conditions of housing and feeding systems.

**Farrowing House for Sows**—by the US Department of Agriculture

Miscellaneous publication No. 1179 gives details of a farrowing house (Plan No. 6076) designed at North Carolina State University, to provide sanitary and comfortable shelter for animals in mild climates and reduce labour requirements for the herdsman.

Enquiries should be addressed to Agriculture Engineer, Extension Service, US Department of Agriculture, Washington DC 20250.

**Flight Mill System for Studying Insect Behaviour**—by L. G. Schoenleber, L. D. White and B. A. Butt

The paper describes the flight mill as being an apparatus that confines an insect to a circular flight path when the insect is attached to a pivoted arm. The development of two-flight arm systems is described by the authors, the first named of whom is an agricultural engineer, the others being entomologists, all with the Agricultural Research Service of the US Department of Agriculture.

Enquiries should be addressed to US Department of Agriculture, Agricultural Research Service, Beltsville, Maryland 20705.

**Hog House Nursery and Finishing**—by the US Department of Agriculture

Published as Plan No. 6075, this hog house design was planned at North Carolina State University as a combined nursery and finishing unit, but may be used as either a nursery or a finishing unit only.

Further details can be obtained from the Agricultural Engineer, Federal Extension Service, US Department of Agriculture, Washington DC 20250.

## Reprint Service

**It is possible to obtain copies of lectures and articles appearing in the Institution Journal, Yearbook or other publications.**

Any private individual or organization may avail themselves of this service and there is no limit to the quantity of reprints of any one article to any enquirer. However, copies are supplied on the understanding that they will be used for private study only, and are not negotiable.

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In the case of items not available by these means, photographic copies can be supplied at a charge per page, calculated according to page size and the degree of difficulty, if any, of photographic reproduction. Members and Affiliated Organizations of the Institution are eligible to be supplied with up to six items per annum free of charge and post free. All enquiries concerning the Reprint Service should be addressed to:

THE INSTITUTION OF AGRICULTURAL ENGINEERS
EDITORIAL UNIT, PENN PLACE,
RICKMANSWORTH, HERTS.

**Keeping Livestock Buildings Warm**—by the University of Nebraska

This paper discusses features of livestock buildings designed to provide an optimum environment of temperature, moisture, air movement and gas content; special attention is paid to aspects of tight construction, insulation, vapour barriers, insulated doors and windows, and ventilation systems.

The paper is published as Agricultural Engineers Digest 13 (Insulation and Heat Loss) and enquiries should be made to Midwest Plan Service, Iowa State University, Ames, Iowa, USA.

**Milk Meters for Herd Recording**—by the Department of Agriculture, South Australia.

Extension Bulletin No. 41.70 describes a trial carried out during 1969-70 to evaluate the feasibility of using meters in place of the conventional buckets for herd recording. The authors are B. R. White, Dairy Research Officer, and M. A. Liebelt, Dairy Adviser, Herd Recording, Adelaide.

**Preliminary Analysis for the Development of Agricultural University Farm Near Village Ochkera Chak No. 217/RB Tehsil and District Lyallpur**—by M. Rafi, Reader in Agricultural Engineering, West Pakistan Agricultural University.

The paper describes the location and area of the university farm and then discusses aspects of irrigation, water courses, land levelling, farm tractor and machinery requirements, farm service buildings, soil, cropping scheme, and the budget of the land utilization department.

**Safer Handling of Liquid Manure and the Design and Operation of Installations for Liquid Manure**—by Scen-Uno Skarp.

Bulletin No. 338 of the Swedish Institute of Agricultural Engineering traces the history of liquid manure handling in Sweden from the 1950s and then presents the results of current investigation into manure gases. Advice is given on the design and management of liquid manure installations in order to obtain safer handling.

Enquiries should be addressed to the Swedish Institute of Agricultural Engineering, Ultuna, 750 07 Uppsala 7, Sweden.

**SI in Agriculture (including horticulture)**—by W. D. Carr

Recently issued by the Agricultural Education Association, the book is intended as a guide for those engaged in administration, advisory work, authorship, commerce, research and teaching. The publication is in four parts. Part 1 attempts to explain the rules of SI, Part 2 deals with their application to agriculture, Part 3 is entitled 'Selling SI' and is based on the experiences of the author and his colleagues in introducing SI to students and farmers, and Part 4 is concerned with the conversion of reference material from imperial units to SI. The author is Chairman of the Sub-Committee on Metrication of the Agricultural Education Association.

Copies of the booklet may be obtained from the Assistant Editor, Agricultural Education Association, Cliftonfield, Shipton Road, York YO3 6RA. Price 26p, post free.

**The Technician in Engineering**—by the Engineering Industry Training Board

EITB Research Report No. 1 is a comprehensively documented survey of the employment, recruitment and qualifications of technicians in the engineering industry in 1969. It is the first research report to be published by EITB.

**Publications**—*from previous page*

The work of the Board since 1969 had identified points on which new information was needed: in particular, clearer definitions of functions in which technicians worked and the jobs they did, and a more accurate estimate of numbers and problems of estimating future requirements. The report offers factual material that should be useful as a source of reference to all concerned with training in the industry. Copies of the report (price 90p) can be obtained from the Engineering Industry Training Board, St. Martins House, Tottenham Court Road, London W1P 9LN.

**Trickle Irrigation**—by the Agricultural Engineering Society, Australia (AESA).

A series of papers on trickle irrigation are set out in Volume 1, No. 3 (December 1970) of Agricultural Engineering Australia.
Enquiries should be addressed to the Editor, S.E.C., 15 William Street, Melbourne 3000, Australia.

**Use of Pneumatic Pressure Extracts of Soil Solutions to Measure Effects of Sulphur Additions to the Soil**—by Arnor Mjos.

Published as Scientific Report No. 17 (Volume 49 1970) of the Agricultural College of Norway, the paper describes an experiment carried out at the Soil Physical Laboratory of the Institute of Fertilization and Soil Management, Vollebekk, to study the suitability of the pressure extraction method in analyses of the effect of sulphate additions on the status of the soil solution.

Enquiries concerning the report should be addressed to the Agricultural College of Norway, Vollebekk, Norway. □

# FORTHCOMING EVENTS

**JUNE 1971**

**WED. 2 to SAT. 5**—BATH & WEST SHOW
Shepton Mallet, Som.

**THURS. 3 to THURS. 10**—ELMIA 71
*International Trade Fair for Forestry, Horticulture and Contractors' Machinery*
Jonkoping, Sweden.

**SUN. 6 to SUN. 20**—RIBATEJO AGRICULTURAL FAIR
Santarem, Portugal.

**TUES. 8 to WED. 9**—ROYAL CORNWALL SHOW
Wadebridge, Cornwall.

**WED. 9 to THURS. 10**—CHESHIRE COUNTY SHOW
Hooton Park, Ches.

**THURS. 10 to SAT. 12**—SOUTH OF ENGLAND SHOW
Ardingly, Sussex.

**TUES. 15 to THURS. 17**—THREE COUNTIES SHOW
Malvern, Worcs.

**FRI. 18 to SAT. 19**—ESSEX COUNTY SHOW
Great Leighs, Essex.

**SAT. 19**—NORTHAMPTON SHOW
Overstone Park, Northants.

**MON. 21 to WED. 23**—NATIONAL (USA) SYMPOSIUM ON SOCIAL AND ECONOMIC ASPECTS OF WATER RESOURCES DEVELOPMENT
*Sponsored by American Water Resources Association*
Cornell University, Ithaca, NY, USA.

**TUES. 22 to FRI. 25**—ROYAL HIGHLAND SHOW
Ingliston, by Edinburgh.

**TUES. 22 to THURS. 24**—CORK SUMMER SHOW
Cork, Eire.

**WED. 23 to THURS. 24**—LINCOLNSHIRE SHOW
Lincoln, Lincs.

**WED. 23 to SUN. 27**—GRASSLAND '71
*Fourth National Grassland Field Day*
Eugene, Oregon, USA.

**SUN. 27 to WED. 30**—ASAE NATIONAL MEETING
*Annual Meeting*
Washington State University, Pullman, USA.

**TUES. 29 to TUES. 6 JULY**—1st INTERNATIONAL FARM MANAGEMENT CONGRESS
University of Warwick, Warwicks.

**WED. 30 to THURS. 1 JULY**—ROYAL NORFOLK SHOW
Norfolk.

**JULY 1971**

**THURS. 1**—I AGR E NATIONAL MEETING
*Selection and Development of New Products*
National College of Agricultural Engineering, Silsoe, Bedford.

**MON. 5 to THURS. 29**—19th INTERNATIONAL COURSE ON RURAL EXTENSION
*Organized by the International Agricultural Centre (Netherlands)*
Wageningen, Netherlands.

**TUES. 6 to FRI. 9**—ROYAL SHOW
*Premier Show of the Royal Agricultural Society of England*
National Agricultural Centre, Stoneleigh, Warwicks.

**TUES. 6 to WED. 7**—VIBRATION AND NOISE IN MOTOR VEHICLES
*Joint Symposium of I Mech E and Advanced School of Automobile Engineering*
I Mech E, 1 Birdcage Walk, London SW1.

**TUES. 13—THURS. 15**—GREAT YORKSHIRE SHOW
Harrogate, Yorks.

**FRI. 16 to SAT. 17**—KENT COUNTY SHOW
Maidstone, Kent.

**TUES. 20 to FRI. 23**—CIGR (Section III)
*Forage drying, mechanized food distribution, machine milking*
Paris, France.

**TUES. 20 to THURS. 22**—EAST OF ENGLAND SHOW
Alwalton, Hunts.

**WED. 21 to THURS. 22**—ROYAL WELSH SHOW
Builth Wells, Brecon.

**TUES. 27 to THURS. 29**—ROYAL LANCASHIRE SHOW
Blackpool, Lancs.

**FRI. 30 to SAT. 31**—BORDER UNION SHOW
Kelso, Roxburgh. □

# BSI NEWS

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

### Director General Talks about the Future of BSI

The expansion of national and world standardization activity, the financing of the British Standards Institution, the format, printing technique and layout of standards, and the change to the metric system were among the subjects covered by Mr G. B. R. Feilden, Director General of BSI in a talk which he gave in Hemel Hempstead on 21 January entitled "BSI in the 1970's". The talk was followed by a general discussion period at which those present were encouraged to give their views, especially on the projected developments in BSI's organization and working methods.

A broad picture of standardization activity emerged from the talk, which was of interest to many people employed in industry or who use British Standards in their work. The meeting was organized by the Standards Associates of BSI, a body composed chiefly of engineers who are the users of standards. Mr Feilden is himself an engineer—well known for the Feilden Report on Engineering Design—and he has earned respect for his forthright way of tackling new approaches to BSI's structure and working methods.

### Safety of Agricultural Trailers

A demand for better braking on agricultural vehicles is apparent in many parts of the world. British users and manufacturers have taken an important step toward greater safety in this field with the introduction of a standard specification for trailer brakes that takes account of several vital factors.

BS 4639 *Agricultural trailer brakes*, published by BSI, specifies requirements for the braking of combinations of agricultural tractors and trailers or implements, fitted with resilient tyres. The standard deals with the braking performance required of various combinations, parameters of coupled tractor and trailer braking systems, and methods of testing the braking performance of these combinations.

The main reason for the growing concern over braking is the trend toward greater weight of trailers and implements. When used on the road, agricultural vehicles mingle with other traffic which must by law be capable of a deceleration of 5 m/s². However, it would be unrealistic to require agricultural vehicles to achieve such a high deceleration since they spend only a small proportion of their time on the road and travel at such low speeds that they can stop within a short distance even with a low deceleration. In any case it is claimed that the cost to the community of achieving high decelerations would be considerable and so the new standard recommends a deceleration of 2.5 m/s².

Manufacturers of equipment complying with BS 4639 may apply to BSI to use the Kitemark. This is a registered trade mark, and its presence indicates an independent assurance that a product complies with a relevant British Standard.

Copies of BS 4639 may be obtained from the BSI Sales Branch, 101/113 Pentonville Road, London N1 9ND. Price by post, remittance with order, 60p (subscribers 50p).

### Further Supplement to list of Common Names for Pesticides

The British Standards Institution has recently published a second supplement to the 1969 edition of BS 1831, containing 32 further recommended common names for pesticides. These new names had previously been published by special announcements in March, May, August and December 1969, and March 1970. The new supplement gives additional details, including recommended pronunciation, full chemical name, structure, other non-proprietary names and a classification of the compounds by use.

Copies of Supplement No. 2 to BS 1831 may be obtained from the BSI Sales Branch, 101/113 Pentonville Road, London N1 9ND. Price by post 50p (subscribers 40p). Remittance with order for non-subscribers.

### Britain Adopts International Recommendations on Testing Meat Products

The implementation by the British Standards Institution of ISO Recommendations on meat and meat products continues with the publication of 4 further parts of BS 4401 *Methods of test for meat and meat products*, and of the first part of a new standard, BS 4635 *Nomenclature of animals for slaughter.*

BS 4401 : Part 3 describes a method for the determination of moisture content, Part 4 the determination of total fat, Part 5 the determination of free fat, and Part 6 the determination of chloride content. With the exception of Part 4 the methods

## INDEX TO ADVERTISERS

are identical with the corresponding ISO Recommendations, the only differences being in editorial presentation. Part 4, however, also gives details of a method widely used in the United Kingdom, but which does not appear in the ISO document.

Full details are given for the experimental procedures and all the reagents and apparatus required. The sampling methods are still under consideration.

Part 1 of BS 4635 gives internationally accepted terms for porcines with the equivalent terms in French. The standard includes definitions for sucking pigs, piglets, young pigs (runners), pigs, boars and castrated boars.

Copies of these standards may be obtained from the BSI Sales Branch, 101/113 Pentonville Road, London N1 9ND. Prices by post are as follows: BS 4401, Parts 3, 5, 6, and BS 4635, Part 1 : 35p (subscribers 30p); BS 4401, Part 4: 50p (subscribers 40p). Remittance with order for non-subscribers.

### New Requirements for Design of Tractors

Developments in tractor design since 1964 are taken into account in the latest edition of BS 1495 *Agricultural tractor details for light and medium tractors.*

There are five new features covered—(1) position, height and load on tractor hook, (2) wheel and hub fitments for tractor disc wheels, (3) location on the tractor of the connector(s) for hydraulic hose, (4) method for operation and location of tractor controls, and (5) mounting pads.

The standard is published at present in imperial units only (Part 1). When sufficient information relating to tractors built to the metric system becomes available, a metric edition will be published as Part 2.

Copies of BS 1495, Part 1, Imperial units, may be obtained from the BSI Sales Branch, 101/113 Pentonville Road, London N1 9ND. Price by post 95p (Subscribers 80p). Remittance with order for non-subscribers.

### Methods of Test for Ammonia Solution

The British Standards Institution has published BS 4651 : 1971 *Methods of test for ammonia solution,* a new standard providing methods for the analysis of technical grade ammonia solution suitable for general purposes. Methods are given for the measurement of density, and determination of ammonia content, residue on evaporation and residue on ignition, iron, chloride and carbon dioxide contents. An appendix gives safety precautions and notes for guidance on sampling.

Manufacturers of ammonia complying with BS 4651 : 1971 may apply to BSI to use the Kitemark.

Copies of BS 4651 : 1971 may be obtained from the BSI Sales Branch, 101/113 Pentonville Road, London N1 9ND. Price by post 50p (subscribers 40p). Remittance with order for non-subscribers. □

BOOK REVIEW

# Anti-Vibration Mounts for Noise Reduction in Tractor Cabs

by A. H. Hakimi, BSES, BSME

Associate Professor of Pahlavi University. Dr Hakimi's paper presents results of an investigation into the possibility of reducing noise levels in a tractor safety cab by attaching the cab to the tractor frame with resilient mountings.

Six mounts were selected from twelve different designs, the preliminary selection being based on noise and vibration attenuation tests. Tables are given showing the resonant frequency, effective stiffness and damping ratio in the axial, transverse and longitudinal direction for each of the six mounts. Attenuation in each direction is shown graphically for each mount within the spectrum 2 to 2000 Hz. Tests were then carried out with a metal and glass cab mounted on a tractor chassis with each type of mount in turn. It was found that most of the mounts reduced noise from that obtaining in a rigidly mounted cab to nearly the level in a free standing cab held in the same position relative to the tractor but not attached to it. Further tests were made on the four best mounts to assess their strength when used in conjunction with a cab undergoing an impact test. Three of the mounts withstood the test successfully.

The full paper will be of interest mainly to practising designers and research workers in this field.

F.M.I.

## THE INSTITUTION TIE

*Members of the Institution are entitled to wear the Institution tie. As well as being an attractive emblem of membership in its own right it is also a particularly useful means of recognition at meetings, exhibitions, agricultural shows and other events at which members are likely to congregate. The tie is made of crease resisting and hard wearing terylene to a pleasing design displaying in silver the Presidential Badge of office on a background of navy blue, dark green or wine, according to individual taste. Institution ties are available strictly to members only and cost £1 each; any number may be obtained in any of the three colours mentioned. Remittances should be made payable to "I Agr E" and crossed.*

# THE SHAPE OF THE FARM TRACTOR †

by A. R. REECE B Sc (Mech Eng), M Sc (Agr Eng), C Eng, MI Mech E, MI Agr E *

Presented at a Symposium co-sponsored by The Institutions of Mechanical and Agricultural Engineers in London on 6 and 7 October 1970.

Development of the modern farm tractor has settled down into the detailed improvement of a single form that completely dominates production throughout the world, with the exception of the U.S.S.R. The essential tasks that the tractor must perform are described, together with the technical requirements imposed by the agricultural environment. It is shown that in the future very little real improvement in performance can be obtained without a radical change of form. Such a change only occurs when new performance standards are required and new technological possibilities are available. The likelihood of such a change is discussed.

## Introduction

Tractor production throughout the world has settled down into a small number of distinct tractor forms. Skid-steered tracklayers, tool-frame tractors, and the conventional two-wheel drive (2 W.D.) machine and its four-wheel drive (4 W.D.) variants. The 2 W.D. machine consists of two of the largest practicable wheels rigidly connected to a relatively heavy engine by a strong tubular frame containing the transmission. The engine is used as a counterweight to implements lifted behind the wheels, the resulting bending moments being adequately resisted by the massive frame. One or two small wheels at the front support the engine when heavy implements are not being carried. The addition of driven front wheels can be considered as a variant of this form.

The tracklayer is only logical for use on weak frictionless soils, which do not form a large part of the world's mechanized agricultural land. They only exist in large numbers in the U.S.S.R., almost certainly because of the inability of the Soviet economy to make proper cost effectiveness decisions.

Tool-frame tractors are intended to operate implements between their axles, and therefore generally have the engine at the back. It is then found impossible to lift heavy implements behind their rear wheels. They therefore have to plough with a mid-mounted implement that causes a large steering moment, and this restricts them to a single furrow. In turn, this limits the engine size it is worth installing, and they end up as low-powered machines—for which the market is very small.

Production is therefore totally dominated by the rigid-frame, 2 W.D. tractor, with a small proportion of 4 W.D. adaptations. This form was introduced by Ford in 1917, fitted with pneumatic tyres in the 1930s, and made into a thoroughly logical arrangement by Ferguson in the 1940s. Since then, great progress has been made in detailed design and the machine has become much more complex, but no further really significant changes have occurred.

At the present time more engineering effort is being put into the improvement of this basic arrangement than ever before, but real gains in economic performance are tending to zero. Fig. 13.1 shows the well-known S-shaped curve characteristic of the manner in which performance varies with historical time. In the beginning slow progress is made until the right line of development is found, then progress is rapid as science is brought to bear and the important principles are fully exploited. Finally, a period of negligible improvement ensues as the last tiny details are optimized.

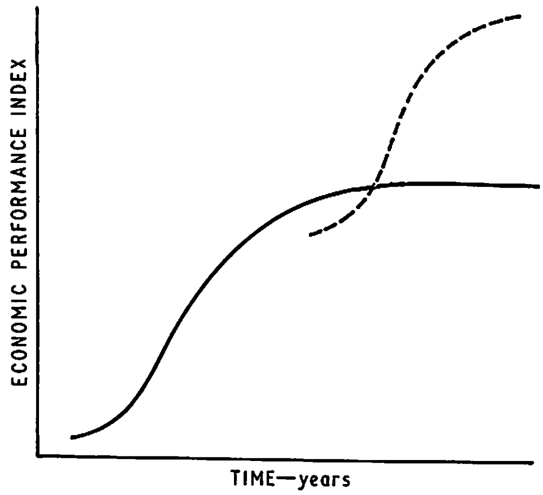


Fig. 13.1. The characteristic S-shaped curve relating improvements in economic performance owing to technological change to the passage of time.

There is little doubt that the farm tractor is in this last stage. The only hope of real improvement lies in a jump on to a completely new S-shaped curve (as shown dotted on Fig. 13.1). This requires a new concept, which in turn requires new technological advances as its basis; and even then economic and social pressures demanding higher performance must be very intense.

What are the prospects of such a new tractor form emerging? Should the goal of a really advanced machine be pursued by industry or government? In order to help answer this question it seems worth while to try to specify the major factors that determine tractor shape and the ways in which tractor performance can be measured and improved.

## Agricultural and Industrial Use

Agricultural tractors form the basis of many industrial machines, but negligible concessions can be made to this use in design. This is because agriculture is fiercely competitive and farm tractors are subject to intense economic pressures holding down first cost. This has caused concentration of production on a small number of models made by a small number of manufacturers, resulting in very low price per lb.

It is this low-cost engine and transmission package that is important in the industrial application, and its existence cannot be threatened by design compromises in favour of industrial use. Where a particular application demands something different, then it is quickly found that the farm-tractor-based machine is rapidly ousted by purpose-built machines, e.g. as in the case of wheeled shovels and forest skidders. Attention can therefore be directed solely at agricultural use.

### The main agricultural tasks

At first sight the farm tractor seems called upon to perform an infinite variety of tasks; however, these can be reduced to the following three functions.

(1) The application of full engine power in the form of a large drawbar pull at low speeds.

(2) The provision of power, mobile support, and control for an infinite variety of attached machines capable of performing a multitude of tasks.

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* Department of Agricultural Engineering, The University of Newcastle-upon-Tyne.

(3) The provision of the basis for an economical fast transport system capable of operating on or off the road.

**The agricultural environment**

The farm tractor must be a universally acceptable exportable machine capable of operating anywhere between the poles (literally) and the equator. The following are the most important characteristics of the environment in which the above three groups of tasks must be accomplished.

(*a*) The surface on which the tractor operates is weak and cannot tolerate excessive loading or deformation without loss of agricultural productivity.
(*b*) The operating surface is irregularly rough.
(*c*) The operating surface is often steeply sloping.
(*d*) Space for manoeuvre is often very limited—very small turning circles are necessary.
(*e*) Operation in growing crops demands high clearances beneath at least some parts of the tractor, and the ability to see the ground within, or close to, the wheelbase.
(*f*) Low-cost operation is essential. The market for 'prestige' machines is negligible (but does exist).

**Technical constraints**

The combination of the three main tasks with the particular features of the agricultural environment imposes certain technical constraints on the design of tractors. The first is due to the requirements of traction, flotation, and tractive efficiency.

**Traction and flotation**

The size of tyre necessary has a great influence on the design of a tractor. If small tyres can be used, then this allows many variations in the shape of the tractor and the layout of its components. The bigger the tyres, the less freedom is allowed to the tractor designer. The size of a tyre is related to the load it carries, inflation pressure, and the amount the tyre is allowed to deflect. The deflection depends on the construction of the tyre and is limited by the onset of failure of the carcass cords. With present-day tyres a maximum deflection of about 25 per cent of the section height is permissible.

A feel for the way in which these variables interact can be gained by the simple analysis illustrated in Fig. 13.2.

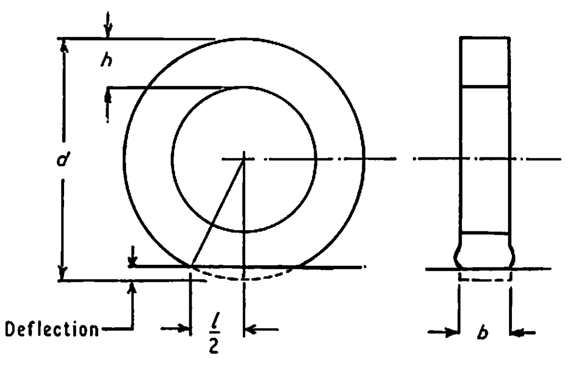


Fig. 13.2. The geometrical relation between tyre dimensions, deflection, and contact length.

Neglecting carcass stiffness, the load carried by the tyre is simply the inflation pressure, $p$, multiplied by the contact area given by the contact length $l$, multiplied by section width $b$. Assuming the tyre to be a square section annular ring with section height $h$, equal to section width $b$, and with 25 per cent deflection, it is easy to show, using Pythagorus, that the contact length is given approximately by

$$l=\sqrt{(bd)}$$

and therefore $W=pb^{3/2}d^{1/2}$

It can be seen, therefore, that the size of tyre required is very much a function of the acceptable tyre pressure, which in turn, depends on the requirements of maximum drawbar pull and minimum flotation.

The maximum thrust, $H$, obtainable from a tyre or track can be simply obtained by multiplying the maximum soil shear strength by the contact area, giving the well-known equation

$H=\Upsilon W=blc+pbl \tan \varnothing$

in which $c$ is the soil cohesion and $\varnothing$ the angle of internal friction. Dividing through by $W=pbl$ gives the coefficient of maximum traction as

$$\triangle_{\text{MAX}}=\left(\frac{c}{p}+\tan\varnothing\right)$$

Most agricultural soils are frictional and $\tan\varnothing$ has a value of about 0·7. The cohesion is necessarily low if crops are to be grown and is not likely to be more than 2 lb/in.$^2$ If the inflation pressure is 10 lb/in$^2$, it can be seen that the cohesive part of the coefficient of traction is less than one-third of that due to friction and can be considered relatively unimportant. Under such conditions the requirements for maximum thrust does not make very pressing demands on tyre size. In a saturated clay, such as is found in a rice paddy, the matter is, of course, entirely different. There is no frictional component, and contact area and therefore low inflation pressure becomes of paramount importance.

Low inflation pressure is necessary for another reason. In order to be productive, agricultural soils must be weak enough to allow rapid root penetration and porous enough to permit drainage and the passage of air to the roots. The strength is related to the pore space; the denser the soil becomes, the greater the strength and the more difficulty air, water, and roots have in penetrating it.

The whole object of agricultural tillage is to maintain soil in a loose, weak state. In this state it cannot withstand high stresses without excessive compaction. The compaction is also undesirable because it results in deep ruts, which make accurate or fast work on the surface impossible. The actual stress levels acceptable to agricultural soils are not understood in a theoretical way. However, there is growing evidence that on a large number of soils over a wide portion of the world's surface the present minimum inflation pressure of 12 lb/in$^2$ is, if anything, rather excessive. It seems certain that tyre pressures must go down in the future rather than up.

Another important factor leading towards the use of very large tyres is the question of tractive efficiency and slip and rolling resistance. The overall tractive efficiency $\eta$, is given by

$$\eta=\eta_m \times \frac{D}{D+R} \times (1-i)$$

where $\eta_m$ is the mechanical efficiency, $D$ the drawbar pull, $R$ the rolling resistance, and $i$ the slip. For a wheeled tractor at maximum drawbar horsepower the slip, $i$, can be as high as 20–30 per cent. It is approximately inversely proportional to the contact length, and this is roughly proportional to $\sqrt{(bd)}$, as has already been shown. Similarly, rolling resistance goes down with contact area and particularly with contact length. Therefore a reasonably high tractive efficiency demands a large-diameter tyre of the greatest possible width.

By now it becomes apparent that the requirements of maximum drawbar pull, minimum compaction and sinkage, and minimum slip and rolling resistance are best served by a long, narrow track, then by a low-pressure tyre of large diameter, and finally, worst of all, by a high-pressure tyre or rigid wheel.

One other consideration that must be borne in mind is the internal rolling resistance of these devices. This is a maximum and very high for a track, much less but still appreciable for a soft tyre, and negligible for a hard tyre. In the case of a driven wheel or track, the internal rolling resistance is overcome by direct application of engine power, which is not too serious. In the case of an undriven element, e.g. the steering wheels of a tractor or the wheels of a trailer, this internal resistance has to be overcome by additional traction from other wheels or tracks. This can be a very serious matter indeed. It is the reason why undriven elements are usually in the form of relatively high-pressure tyres and only very rarely are tracks used.

A major variable affecting the type of ground-drive equipment used is the duty of the vehicle. This can vary from the task of developing traction, as in tractor, through carrying loads that are large relative to the vehicle weight, as in a dump truck, to self-propulsion only, as in the case of a combine harvester. Yet another variable is the speed of operation.

It is perhaps worth trying to assemble all these variables into two matrices showing how these variables interact. Fig. 13.3 shows the general relation between running-gear type, soil conditions, vehicle duty, and vehicle speed. Fig. 13.4 shows the general relation between the overall vehicle form as determined by number and type of ground-drive elements and operating conditions.

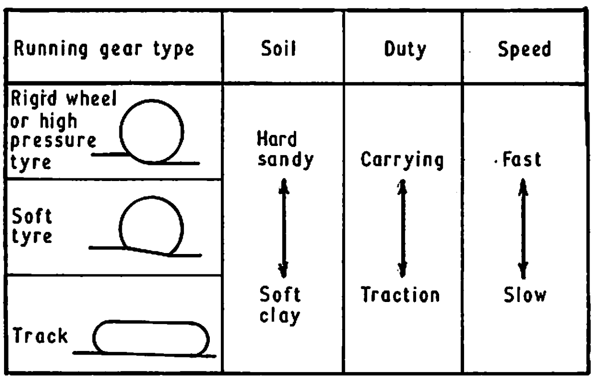


Fig. 13.3 The general relation between running gear type, soil conditions, vehicle duty, and speed.

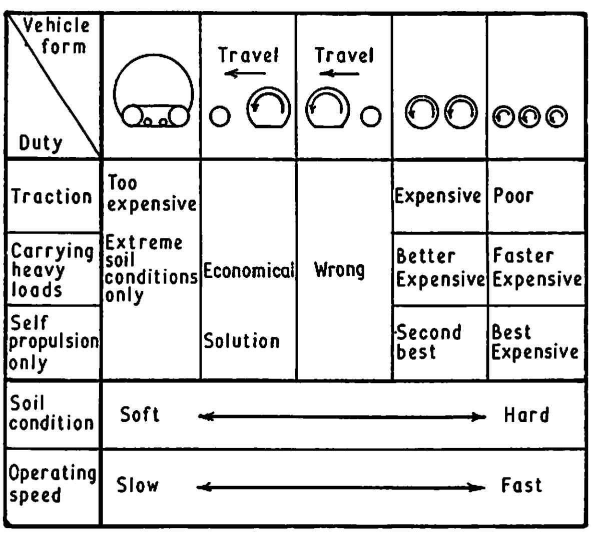


Fig. 13.4 The general relation between vehicle form and vehicle duty, soil type, and operating speed.

It is hoped that these arguments and diagrams show that an effective farm tractor must have a small number of very large size wheels. Machines with truck-type form may meet certain specialized markets but they will never attain very large sales into general agriculture.

**Implement location**

The shape of the tractor is greatly influenced by the location of the implements that it has to operate. In general, they can be mounted in front, between, or behind the wheels, or out at the side. Side mounting is generally impracticable owing to the large steering moments it causes. Front and mid-mounting are not generally acceptable for another reason.

A very large part of the tractor's job is cultivation, and a primary function of cultivation is to loosen and weaken soil for the reasons previously discussed. It is not reasonable to run the main load-carrying driving wheels over soil that has been thus loosened and weakened. If this is done, then the soil beneath the wheels will be compressed and strengthened, thus nullifying some of the point of the cultivation.

Even more important is the fact that it is extremely difficult and inefficient to obtain traction from this loosened, weakened soil. It can quite simply be concluded, therefore, that the most important implements used with a tractor absolutely must be connected behind it, outside the wheel-base.

Since many of the implements that are to be mounted on a tractor are not only heavy but in the case of the plough, very long, it results that the weight distribution of the tractor changes dramatically depending upon the implement it carries, and whether it is lifted or lowered. For a conventional 2 W.D. tractor the weight on the rear wheels can vary by a factor of about 50 per cent.

**Chassis strength**

The requirement just mentioned, that heavy loads must be carried far outside the wheelbase of the tractor, imposes very large bending moments on the tractor chassis. These moments can be greatly increased by inertia forces. A particularly destructive attachment in this respect is the hydraulic loader.

At one time, tractors were often made as an open framework into which were fitted the engine, clutch, gearbox, and final drive as separate boxes. This has proved an utterly inadequate solution, and the use of a single large tubular frame containing the transmission is now universal.

## Economic Performance

The prices realized by farm crops are everywhere under strong pressure either from vigorous competition, in the case of underdeveloped countries, or deliberate government policy, in the industrialized countries. Wherever tractors are used, this pressure is tending to drive labour from the land, substituting capital in its place. When applied to the tractor, this results in a steady trend towards higher powered tractors and lower cost operation.

The costs of operating a tractor can be divided into two parts, one part depending on its first cost, and the other part depending on running costs. Running costs are roughly proportional to energy expended and are no longer capable of much reduction. The main improvement to be sought in economic efficiency must therefore come from a reduction in the first cost of the tractor.

The first cost of machinery of a particular class is quite closely proportional to its weight. This is true even allowing for quite considerable variations in form, complexity, and detailed design. It is particularly true in the case of tractors over a very wide range of forms, including wheeled tractors and agricultural and industrial crawlers, quantity-produced machines tending to have the same cost per lb weight.

The main variable in altering the cost per lb is likely to be volume of production. Complexity does not seem to be of great significance.

The main conclusion of this section, therefore, is that the primary avenue for improvement in economic performance is by means of a reduction in tractor weight per unit of installed engine power.

## Power, Weight, and Speed Relationships

The weight per unit of engine power is determined by the necessity for developing the engine power in the form of drawbar pull; it is therefore, very much a function of operating speed. It has been shown previously[1]* that

* *References are given in Appendix 13.1.*

this relationship can be approximately described by the following equation:

$$\frac{W}{E} = \frac{\eta(I-i)}{(K\mu+e)v}$$

where $W$ is the total tractor weight, $E$ the engine power, $\eta$ the transmission efficiency, $i$ the slip, $e$ the coefficient of rolling resistance at maximum, $\mu$ the coefficient of traction at maximum d.b.h.p., $K$ the proportion of the total tractor weight applied to the driving wheels, and $v$ the actual field speed allowing for slip.

The weight utilization factor $K$ can vary from 0·6 for a 2 W.D. tractor without ballast and no load transfer to 0·9 with either a lot of ballast or a lot of load transfer. For a 4 W.D. tractor it can vary from 1 to 1·2 when using the maximum load transfer from a heavy plough.

This extremely simple relationship between power, weight, and working speed is shown plotted in Fig. 13·5 which represents 2 W.D. tractors and 4 W.D. tractors in good tractive conditions. The graphs can be effectively summarized by means of the figures given in Table 13.1.

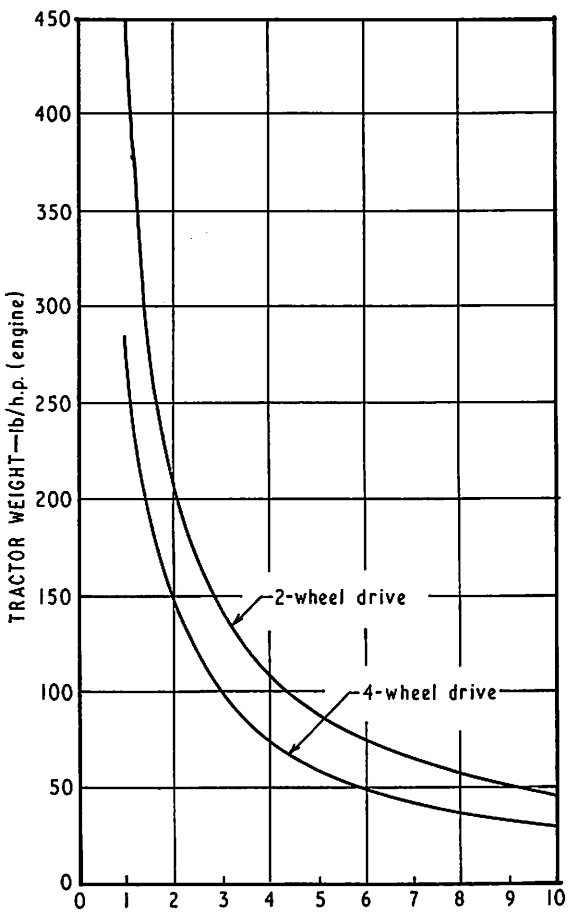


Fig. 13.5 The relation between tractor weight per horsepower and working speed for both 2 W.D. and 4 W.D. in good conditions for traction.

**TABLE 13.1**

| | Required weight, lb/hp | |
|---|---|---|
| Field speed, mile/h. | 2 W.D. | 4 W.D. |
| 1 | 440 | 310 |
| 4 | 110 | 77 |
| 6 | 73 | 51 |
| 8 | 55 | 39 |

These figures may be compared with those actually found in practice by reference to the following data. The John Deere range of tractors weigh between 90 and 120 lb/hp. They represent, therefore, reasonably proportioned machines for operation at around 4 mile/h., or at faster speeds in conditions where load transfer is not available, as is often the case on the hard soils found in the U.S.A. The Massey Ferguson range are the lightest tractors in the world with weights per horsepower around 75 lb/hp. These tractors are therefore proportioned for operating at 6 mile/h., or alternatively they need considerable ballast.

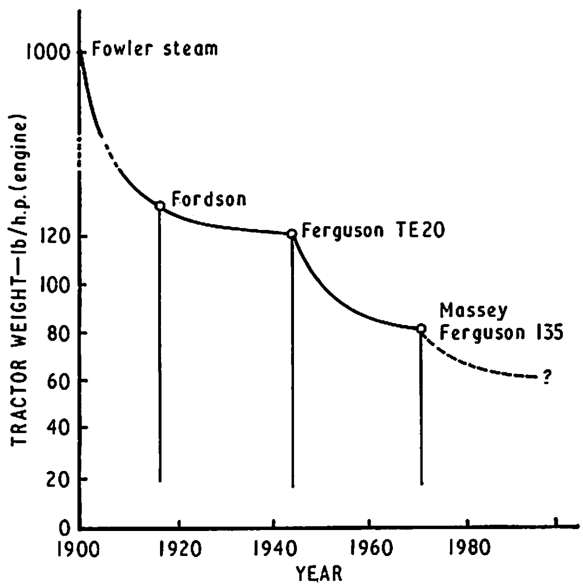


Fig. 13.6. The reduction in tractor weight/power ratio as a historical process.

The change in tractor weight/power ratio viewed as a historical process is shown in Fig. 13.6. During this century there are two main phases. The first is the enormous reduction in weight made possible by the change from steam to internal-combustion engines. The second is the long period of consolidation in which tractor weight/power ratios remained at 120 or above. During this period working speeds remained as low as 2 mile/h. From 1947 to the present date there has been a second spectacular reduction in tractor weight. This has been made possible by the increase in working speeds up to around 4 mile/h., and the much better use of tractor weight made possible by the universal adoption of the draught control system invented by Harry Ferguson.

The above considerations indicate a new goal that could possibly be made the aim for an advanced tractor design. This would be a machine capable of working at 8 mile/h. and weighing not more than 55 lb/hp for a 2 W.D. machine or 40 lb/hp for 4 W.D. drive. These figures are extremely low. It seems that the 70 lb/hp achieved by the lightest Massey Ferguson tractor is about the lightest weight that can be achieved economically using current technology and the current tractor shape. Lower weights can, of course, be achieved, e.g. by substituting titanium for steel, but only at increased cost. The lower weight that is required must be achieved by optimizing the design and improving the overall concept.

It is evident that such a dramatic increase in power-to-weight ratio can only be achieved by a combination of new concepts and the utilization of advanced technology.

## Ergonomic considerations

The foregoing arguments point to the necessity for increased power and increased operating speed; but both these factors impose very serious ergonomic problems. It has now become fairly well established that contemporary tractors damage their drivers physically. The average tractor driver suffers greater spinal damage and more stomach disorders than the average industrial worker. These two effects are almost entirely due to the rough ride caused by the present unsprung tractor being driven over rough field surfaces. Tractor drivers also suffer from a greater reduction in hearing ability than the average industrial worker due to the excessive noise mainly from the tractor engine.

The higher the power installed in a tractor the worse these two factors become. This is because the noise output grows with engine power, and because the higher the tractor power the more likely it is that it will have to be driven fast in order to use this power. The tractor driver has, of course, a very simple remedy, i.e. simply to throttle down, at least when his employer is not in the field. This is an almost universal solution.

An impressive investigation carried out by the National Agricultural Advisory Service[2] has shown that 100 hp tractors do not accomplish any more work in the field than the largest regular 65 hp machines, even though they cost twice as much to purchase. This particular investigation is typical of many others that have been carried out to show quite clearly that the limitation on performance of farm tractors is now almost entirely due to the almost intolerable conditions imposed on the driver when working at full power. This situation gets worse as the power of the tractor increases.

The bad ride of the conventional tractor is due to the fact that its natural frequency of oscillation on its tyres lies in the range 3–4 Hz. This coincides with the natural frequency of the oscillation of the internal organs, and it is one of the least tolerable to the human body. It seems certain that this problem can only be overcome by the provision of either a suspension to the whole vehicle or a fully suspended cab. The latter solution is likely to be completely unsound.

If a tractor is driven fast over rough ground, very high inertia loads are applied to the whole of the tractor and any implements it is carrying. If the driver is insulated from these inertia loads, then there is nothing to stop him wrecking the machine; experience has already shown that this is exactly what happens. It seems necessary, therefore, to have a proper, complete suspension system that protects the whole machine and not only the operator.

The modern lightweight, high-speed diesel engine produces an intolerable level of noise. In modern truck construction this noise is tolerated because it can be prevented from reaching the driver's ears. This is achieved by suspending the engine relative to the cab and chassis on a flexible suspension and surrounding it with a sound-absorbing box.

In the current tractor concept this solution is not possible because the engine is used as a counterweight and rigidly connected to the chassis. Engine vibrations are therefore transmitted throughout the tractor and radiated from all its surfaces. This means, for example, that most cabs fitted to tractors increase rather than decrease the noise arriving at the driver's ear.

Safety is another important consideration and at last safety cabs have become obligatory in many countries, and their use will undoubtedly spread throughout the world. The present safety cab is an addition to the tractor weight of the order of 5 per cent.

It seems then that ergonomic and safety considerations will oblige any advanced tractor to have a proper suspension system, an isolated engine, and proper safety arrangements.

## Limitations of the Present Shape

The present form of tractor, using the most advanced of contemporary technology, weighs 70 lb/hp and can work at 6 mile/h. It probably does not do this owing to the inadequacy of its ride and its excessive noisiness. The current development trends are simply concerned with increasing the power installed in such a tractor; while this makes possible increased rate of work in the hands of company demonstrators, it does not lead to much more work when driven by ordinary farm workers. This gives rise to the current pressures from both customer and government for safer, more humane machines. Attempts are being made to meet these demands by the addition of various features, such as sound insulation, safety cabs, partial suspension, etc. These additions increase the weight of the tractor and make it impossible to conceive of any genuine reduction in first cost.

## Is a New Concept Possible?

There appear to be two forces which cause new forms of machine to be developed and to replace old forms. The first of these is changing and developing economic and social forces. The second is the steady advance of technology in general. This makes possible the development of new concepts based on new devices.

In the case of the agricultural tractor there appears to be at the present time some new forces at work in the economic and social scene. The pressure for improved economic performance is maintained and, if anything, intensifies. The new forces are those concerned with safety and driver health. These are likely to be exercised through government legislation.

There are a great many technological developments which are not yet exploited fully in a contemporary tractor. Examples are the development of lightweight high-torque hydraulic motors suitable for direct incorporation in tractor wheels. With these have come the development of much cheaper, quieter, and more reliable variable delivery pump systems. There have also been great advances in the development of controllable hydropneumatic suspension systems that seem capable of solving all the problems of tractor ride and variable weight distribution.

The development and use of centralized constant pressure hydraulic systems capable of simultaneous operation of many services has an important bearing on the preceding two items. Developments in engine technology are also relevant, particularly the trend towards lightweight, high-speed, turbo-charged engines.

These and many other changes in the field of new materials and components appear to add up to a strong possibility of a radical step forward—the possibility of a machine fulfilling all the demands of the main agricultural tasks but capable of doing these at much higher speeds with great comfort and safety for the driver. This, however, will only be achieved by fairly radical changes of form and shape.

The foregoing discussion attempts to show that the time is now ripe for a serious attempt to advance tractor design by means of a major leap forward. The argument attempts to show that technical, social, and economic conditions favour such a development. However, it must be pointed out that there are also powerful organizational forces tending to prevent such a change.

The tractor industry has the prime mission of providing a steady flow of effective tractors to markets distributed throughout the world. It must support these tractors with adequate spare parts and repair facilities. These aims have been achieved at remarkably low cost by the development of very large centralized production organizations with huge networks of dealers and distributive channels. The scale of these operations have enormously complicated the consequences of even the smallest change. For example, it now takes about a year to institute a small design change in a modern tractor.

Large organizations devoted to such enormously complex tasks arc inherently incapable of making rapid change. This can be illustrated best by considering the consequences of introducing a complete new range of tractors of absolutely conventional design. When this was last done

*Please turn to page 43*

# A STUDY OF TRACTOR NOISE CONTROL †

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A high incidence of hearing loss has been encountered among tractor drivers, and noise levels are shown to be further increased by the addition of cabs, particularly those which are structurally strong to resist crushing if the vehicle overturns. Some reductions in the noise level of the operator's environment can be obtained by covering the engine or by exhaust system modifications, while possible future improvements to diesel engine design may effect a significant improvement. However, it is proposed that noise reduction is likely to be achieved by attention to acoustic features of the operator's cab. The inclusion of resilient mounts, substantial floors and bulkheads, and acoustically absorbent linings are all shown to provide worthwhile improvements and, in combination, these measures can reduce noise levels from more than 100 dBA to 90 dBA or less. Where the tractor is fitted with a safety frame only, a low noise fabric cladding is shown to be feasible.

## Introduction

A high incidence of hearing loss among tractor operators has been reported by research workers in a number of different areas[1-4]‡, the most recent publication covering a survey of the hearing of tractor drivers in the U.K. In this latter survey[1], evidence of noise-induced hearing loss was apparent with 36 of the 70 tractor operators submitted to audiometry tests, and in approximately half of these cases the speech frequencies were affected. Each of the other reported surveys also indicated a relatively high incidence of hearing loss, and in all cases there is considerable evidence that this is caused by the noise exposure on the agricultural tractor.

Experiments by Huang and Suggs[5] with reproduced tractor noise have suggested that steering and problem solving ability, although not significantly affected by steady tractor noise or shorter periods of exposure, is somewhat affected by changing intensity levels of noise of a tractor type and by long exposures. A probably more important way in which excessive tractor noise affects performance is that it is liable to limit the rate at which an operator will drive his machine. This has been indicated by surveys by the National Institute of Agricultural Engineering, showing that in ploughing and heavy cultivation tasks the speed of travel is frequently set below that of which the tractor and implement are capable by the unwillingness of the operator to withstand either the higher noise levels or severe ride vibration which would both arise from higher speeds.

Statutory limits to noise at the tractor operators position have been established in some countries, notably in eastern Europe and in Sweden. Less formalized criteria for hearing conservation have been proposed by research workers, notably Burns[6] and Kryter[7], generally in relation to a weekly noise exposure of approximately 40 h. Although an agricultural tractor driver would not normally work continuously throughout the year on a tractor, during busier periods he might drive for much more than 40 h per week, and also when not on the tractor he may be operating other noisy machinery such as combine-harvesters. Taking into account the somewhat limited data available on tractor exposure times and the varying noise levels associated with different tractor operational tasks involving different engine speeds and loads[8], we have proposed the value of 90 dBA as an objective limit for maximum noise emitted by the tractor to ensure minimal hearing loss risk and operator annoyance[9].

Noise emission as it affects those off the vehicle is regulated by the Ministry of Transport Road Vehicle Noise Regulations[10] in the U.K. and by similar regulations in other countries. It is clear from routine measurements made during tests of tractors that these regulations can generally be met without further special measures, other than possibly the adoption of more efficient silencers for the more stringent national requirements.

From the evidence of noise-induced hearing loss and operating speed limitation it is clear that operator noise levels on tractors are unsatisfactory. The studies reported in this paper were aimed at discovering through a detailed analysis of the relative importance of the different noise sources on a tractor and of the transmission paths of noise to the operator's vicinity, means by which the noise level at the operator may be reduced to comply with the proposed hearing conservation criteria. Although the paper sets out to quantify the individual noise contributions, the accuracy of this quantification is limited by the impracticability of completely removing effects from other sources while investigating one specific source. Nevertheless, the quantitative data on noise levels of individual sources are meaningful on a relative basis and all overall noise levels are more accurately definable.

## The Operator Noise Environment

### Methods of noise measurement

With the exception of measurements of engine and transmission noise components and some noises in a cab, all measurements were made on a moving vehicle with a draught load applied by a hydraulic dynamometer car, towed at a sufficient distance from the tractor to avoid influencing the operator's noise environment. The measurement microphone was attached to a specially constructed headgear and arranged to be approximately in the plane of the operator's forehead and 5 cm from the temple (Fig. 16.1*a*). Auxiliary measurements investigating the effect of precise microphone positioning on the measured results are reported in Appendix 16.1. The microphone was connected by a standard 3-m extension cable to a sound level meter and for spectral analysis to an octave/one-third octave filter set and level recorder. All noise analyses were carried out without prerecording and, therefore, test runs had to be of sufficient length to allow adequate time for filter switching and level recording on the paper charts. Calculation of loudness values in sones was carried out from octave band pressure values according to the method 'A' of ISO Recommendation R.532[11].

Engine and transmission component noise values were assessed with these components sited in an anechoic enclosure made from bales of straw. Appendix 16.1 also outlines the construction of this enclosure and acoustic measurements made of its validity. In this case no operator was present but the microphone was sited at the appropriate position after trials had established that the presence of the operator was not important. Power from the engine was absorbed by a water-brake dynamometer sited outside the enclosure.

Preliminary experiments were made to determine the effect, with or without a cab fitted, to the tractor of operator size and dress and of the type of ground over which the vehicle was operated (see Appendix 16.1). It was shown in these preliminary tests that it was generally not necessary to take these factors into account in the main investigation.



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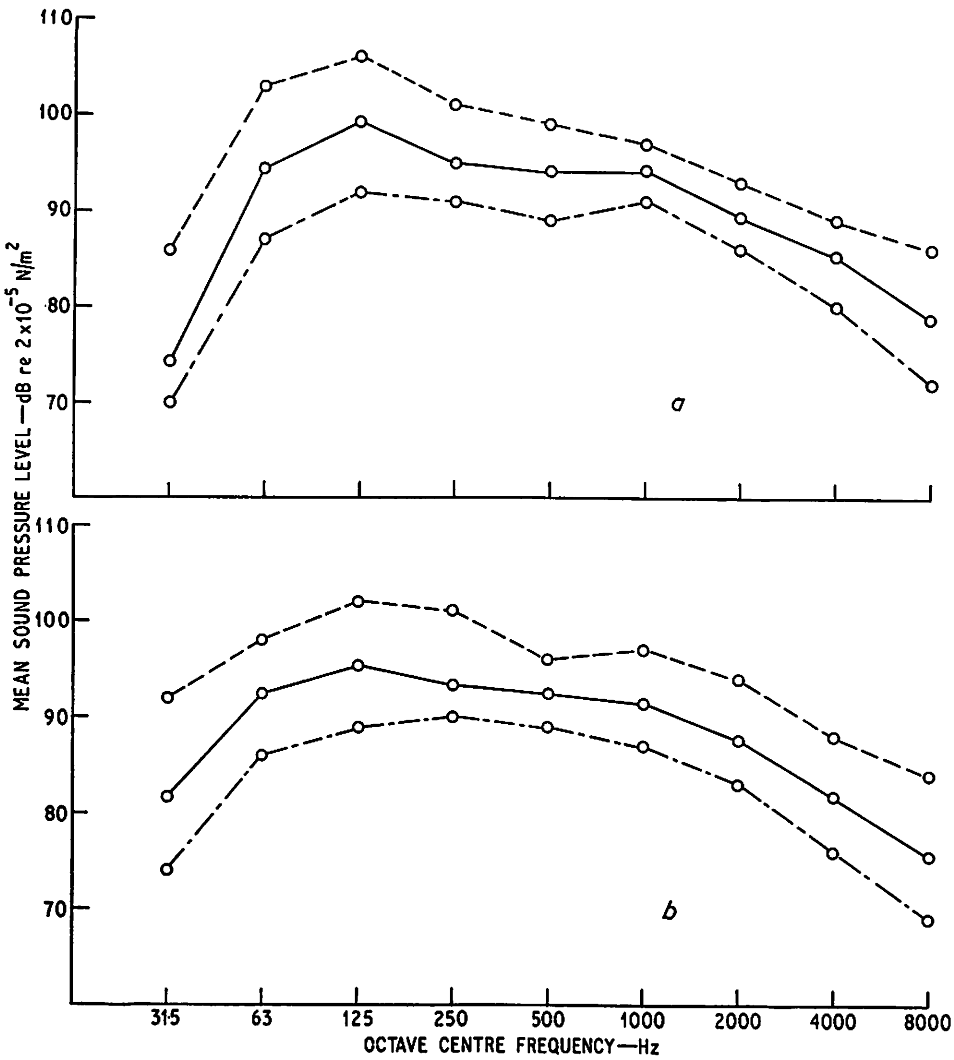
‡ References are given in Appendix 16.2.




*a* At 85 per cent maximum power at approximately 4·5 mile/h.
o— — —o maximum values 100·5 dBA o————o maximum values 97 dBA o— — — — —o minimum values 93·5 dBA.

*b* at maximum speed with a light load.
o— — —o maximum values 98 dBA o————o mean values 94·5 dBA o— — — — —o minimum values 90 dBA.

Fig. 16.1. Octave spectrum variability in tractor noise measurements (No cab).

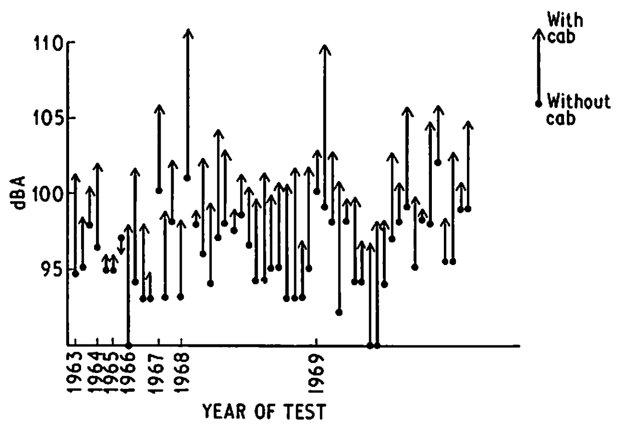



Fig. 16.2. Summary of effect on operator noise level of safety cab added to the tractor from N.I.A.E. tests.

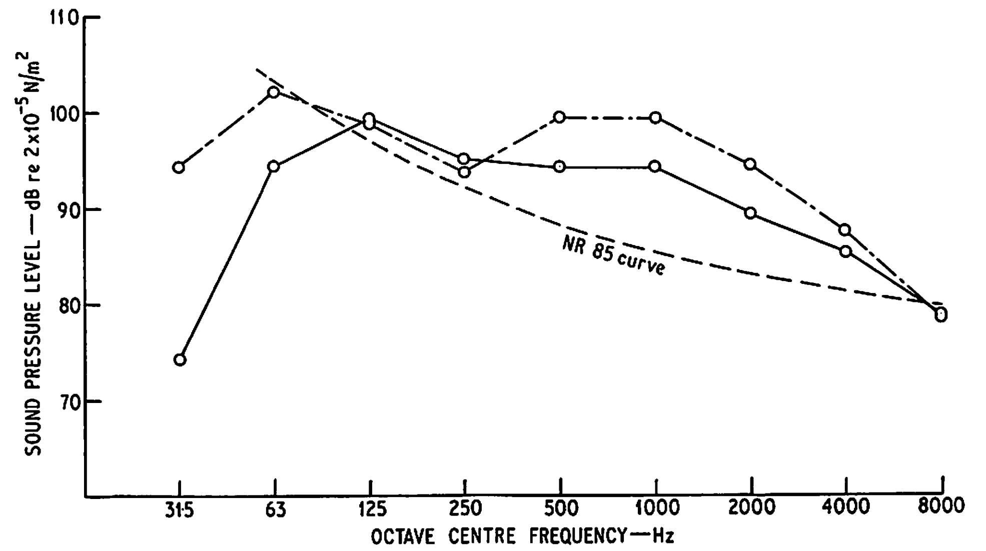
Official test data reported below were obtained from noise measurements made as part of the formal tests at the National Institute of Agricultural Engineering of agricultural tractors and safety cabs.

In the following sections the data, which are specifically related to one vehicle and its component parts, were obtained on a production 52-hp model with a three-cylinder diesel engine and two-wheel drive. At the commencement of the measurements, which spread over a period of approximately 18 months, the vehicle was only a few months old and throughout was in good mechanical order. The measurements, made with a fitted safety cab, were with a commercially available cab modified for these studies at the N.I.A.E. This cab was also in a new condition.

**Sound levels and spectra**

Fig. 16.1*b* summarizes octave band pressure levels for 12 tractors (power range 45–100 hp) recently tested, with the noise measurements made (*a*) at 85 per cent of maximum obtainable power at a forward speed of approximately 4·5 mile/h and (*b*) at maximum forward speed with no drawbar load. Judged by the proposed 90-dBA objective the noise of all the tractors tested was unsatisfactory. The octave spectra demonstrate the dominance of the 125-Hz component close to the engine firing frequency, particularly when the engine is loaded, but the higher frequency component centred around 1000 Hz is likely to be as important pyhsiologically due to the greater effect of higher frequency noise on hearing [6]. This component, characteristic of diesel engine noise, arises mainly from combustion or piston excitation of vibration of the engine structure.

Routine measurements of noise in safety cabs fitted to tractors (Fig. 16.3) indicate that in the great majority of cases the noise to which the operator is exposed within the cab is significantly greater than that on the particular




o– – – – – –o mean spectra with cab o————o mean spectra without cab.

Fig. 16.3. Comparison of mean octave spectra from measurements with and without a safety cab fitted.

model of tractor without a cab fitted. This increase is examined in some more detail in Fig. 16.3 where the mean spectra for tractors with and without cabs are compared and shown, together with the NR 85 curve which has been proposed to be indicative of the hearing damage risk of noise at different frequencies. It is clear that the important increase caused by the cab is in the range 250–4000 Hz.

**TABLE 16.1**

**Summary of environmental noise levels from recent O.E.C.D. tractor tests**

| P.t.o., hp | 14 | 32 | 36 | 52 | 53 | 57 | 59 | 62 | 62 | 65 | 65 | 68 | 69 | 74 | 93 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Noise, dBA | 81 | 82 | 83 | 87 | 88 | 86 | 92 | 86 | 87 | 88 | 90 | 84 | 88 | 87 | 90 |

Noise levels of tractors recently tested under the standardized procedure for bystander noise[10] are listed in Table 16.1. These have all complied with the U.K. regulations in force at the time, although some would have exceeded the current limit of 89 dBA. It appears likely that this could be achieved with a more efficient silencer.

### Analysis of sound sources

Normal noise characteristics of the tractor and cab used in the reported study are detailed in Fig. 16.4, the attachment of the cab increasing the noise level at the operator from 98·5 to 103 dBA.

*Engine*

Many papers have dealt with the subject of diesel engine noise, notable among them being the work of Priede *et al.*[12] while a recent comprehensive review has been made by Soroka *et al.*[13]. In view of the large amount of published information on noise sources within the engine, these will not be discussed further, but as important noise components arise from different functions of speed and torque, the relationship between these variables and total noise level at the position occupied by the tractor operator has been examined.

These measurements were made with the engine detached from the clutch and transmission housing and with the load dynamometer coupled to the flywheel.

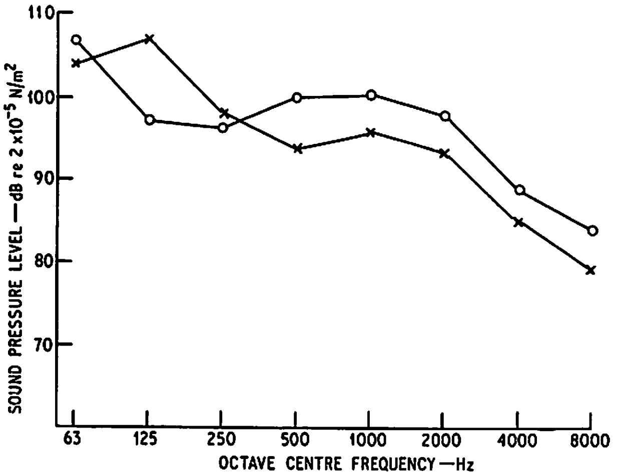
The measured data are summarized in Table 16.2 and one-third octave spectra for conditions of high and low speed and torque are given in Fig. 16.5*a* showing the spectral shape to be little affected by the operational conditions of the engine.

**TABLE 16.2**

**Operator noise contribution, dBA (and sones) from three-cylinder 52-hp engine with various load conditions**

| | Engine speed, rev/min | | | | | |
|---|---|---|---|---|---|---|
| Torque, lb ft | 900 | 1200 | 1500 | 1800 | 2100 | Maximum* |
| | | | (*a*) Engine only | | | |
| Max. | 85 (51) | 88 (65) | 91 (78) | 93 (97) | 95 (119) | 97 (132) |
| 100 | 82 (45) | 86 (59) | 89 (72) | 92 (85) | 95 (114) | 97 (132) |
| 80 | 81 (42) | 85 (56) | 89 (71) | 91 (75) | 93 (105) | 96 (122) |
| 60 | 80 (36) | 84 (51) | 88 (67) | 90 (73) | 93 (102) | 96 (115) |
| 40 | 79 (37) | 83 (44) | 87 (59) | 89 (68) | 92 (90) | 95 (109) |
| 20 | 78 (33) | 82 (43) | 85 (54) | — | — | — |
| | | | (*b*) Engine and gearbox, sixth gear | | | |
| Max. | — | — | — | — | 97 (122) | 98 (137) |
| 100 | — | — | — | — | 96 (112) | 97 (126) |
| 80 | — | — | — | 93 (86) | 95 (108) | 96 (117) |
| 60 | — | — | 89 (66) | 92 (78) | 94 (100) | — |
| 40 | — | — | 89 (63) | 90 (70) | 93 (92) | — |
| 20 | — | 85 (49) | 96 (54) | 89 (65) | 92 (83) | — |
| | | | (*c*) Tractor drawing loading car, sixth gear | | | |
| Max. | — | — | 94 (101) | 97 (122) | 98 (147) | 98 (161) |
| 100 | — | — | — | — | 96 (114) | — |
| 80 | — | — | — | 93 (84) | 95 (103) | — |
| 60 | — | — | 90 (71) | 92 (82) | 95 (109) | — |
| 40 | — | — | 89 (66) | 91 (77) | 94 (101) | — |
| | | | (*d*) Tractor drawing loading car, fifth gear | | | |
| Max. | — | — | 94 (96) | 96 (112) | 97 (123) | 98 (136) |
| | | | (*e*) Tractor drawing loading car, fourth gear | | | |
| Max. | — | 92 (83) | 94 (99) | 97 (115) | 98 (147) | 99 (145) |

**Rev/min at maximum b.h.p. or maximum d.b.h.p. as appropriate.*




o——o With a conventional safety cab 103 dBA, 180 Sones, NR 101.
×——× Without a conventional safety cab 99 dBA, 145 Sones NR 97.

Fig. 16.4. Operator noise spectra on a 52-hp tractor.

*Transmission*

The transmission housing was reattached to the engine and static noise measurements made with the engine loaded through the p.t.o. shaft to include the noise contribution from connected gears. Increases of 1–2 dBA above the equivalent level with engine only were measured (Table 16.2).

The contribution from the full transmission train was assessed by operating the tractor on a tarmacadam test track with dynamometer car loading. Table 16.2 shows the additional transmission contribution to be 1–2 dBA. Fig. 16.5*b* shows the transmission contribution to be mainly of higher frequency. It is well known that transmission noise can vary considerably between different tractors of the same nominal model, particularly at specific speeds, and in one case two tractors of the same model have been found to differ by as much as 5 dBA.

*Engine components*

The contributions from various sources on or associated with the engine were assessed (Table 16.3) by suppressing the noise transmission from each source in turn and measuring the resulting decrease in overall noise level. The suppression measures taken were, in the case of air intake or exhaust outlet, to add diversion pipes to channel air flows from the manifolds to the front of the vehicle, at which position they were screened from the operator position and were assumed to make an insignificant noise contribution. The engine wall and sump components were eliminated by absorbent barrier screens of glass fibre, polyurethane foam, steel, or lead sheet. The fan contribution was eliminated by removing the fan belt.

**TABLE 16.3**

**Tractor and cab noise component levels (dBA)**

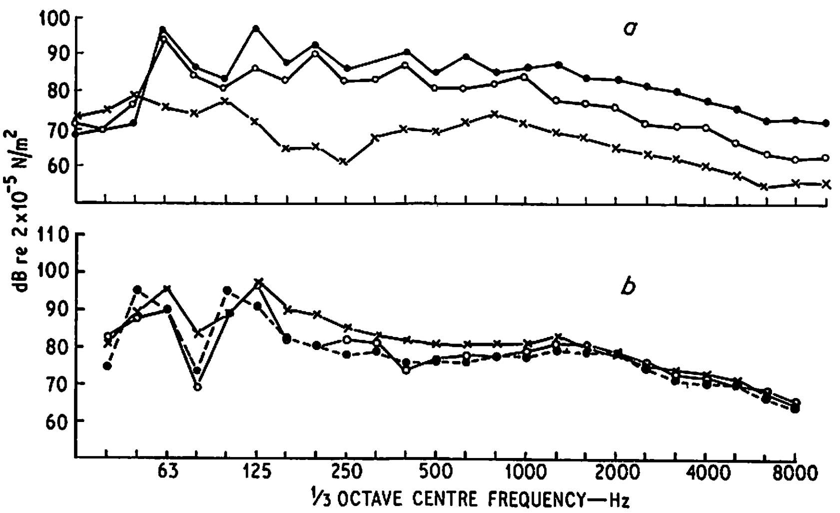
52 b.h.p. tractor at maximum d.b.h.p. in fourth gear. Noise measurements at operator's ear position.

*Total noise:* Tractor only, 99 dBA (146 sones, NR 96)
Tractor with typical safety cab, 103 dBA (178 sones, NR 101)

| Noise source | Tractor only, dBA | Tractor with typical safety cab, dBA |
|---|---|---|
| Exhaust, standard | 93 | 88 |
| Exhaust unsilenced | 107 | — |
| Inlet, standard | 91 | — |
| Inlet, unsilenced | 93 | — |
| Pre-cleaner | 86 | — |
| Fan | 90 | — |
| Fuel tank and cowl | 87–91 | 93 |
| Transmission | 90 | 90 |
| Engine walls upper plus cylinder head | 92 | 95 |
| Engine walls lower plus sump | 84 | — |
| Hydraulic pump | 87 | — |
| Injector pump | 86 | — |
| Fenders | 84 | — |
| Cab structure | — | 98 |
| Lower bulkhead area | — | 97 |
| Windscreen | — | 78 |
| Roof | — | 89 |
| Floor area | — | 88 |

*Vehicle Structure*

By removal of vehicle structural components in turn the contributions by the fenders, floor, and fuel tank were assessed (Table 16.3).




*a* ×——× 800 rev min no load 79 dBA, 32 Sones, NR 77
o——o 2050 rev min no load 90 dBA, 61 Sones, NR 85
●——● 2050 rev min max d.b.h.p. 96·5 dBA, 90 Sones, NR 95
*b* o— — —o Engine only driving water brake at max load 97 dBA, 132 Sones, NR 97·5
o——o Engine and gearbox driving water brake gear 6 max load 98 dBA, 137 Sones, NR 98
×——× Tractor on loading on gear 6 max load 99 dBA, 161 Sones, NR 99

Fig. 16.5. Engine noise spectra measured at the operator's position with varying operating conditions.

*Cab*

It became obvious that with a cab fitted the importance of various noise sources was considerably altered. Additionally the cab structure itself generated considerable noise as a result of vibration excitation from the engine and transmission. This noise component was assessed by removing the mechanical link between cab and tractor chassis while retaining the cab in its normal mounting position by supporting it from the floor. Its noise emission was then calculated from the total noise with and without cab attachment (Table 16.3). Other noise components with the cab fitted were isolated by screening or other appropriate measures.

## Control of Tractor Noise

### General

By reference to Table 16.3 it is clear that the presence of a cab can considerably reduce the noise contribution from many sources—the exhaust outlet, for example. Other contributions, such as noise radiated from the engine walls, may be reduced by a solid bulkhead between engine and operator. The reduction of operator noise level may thus be related to a large extent to the design of an operator's cab. However, in addition there are aspects of engine design and housing which can lead to significant modification of the noise level and which must be taken into account where no cab is to be used or where very large noise reductions are essential.

### Engine design

A considerable amount of research has been carried out over the last few years into reduction of diesel engine noise by modification to the conventional design of engines. The work of Priede *et al.*[12], for example, has demonstrated methods of reducing noise loudness adjacent to the engine by a factor of 2. The specific measures giving this order of reduction are:

(*a*) modification of the main crankshaft bearing mounting structure to incorporate a rigid horizontal beam structure, thus reducing noise generated from horizontal bending vibration of the engine;

(*b*) choice of high rigidity covers for valve gear and any other engine auxiliaries to avoid undue resonance vibration;

(*c*) replacement of the cast sump by a thin metal cover carefully chosen to avoid resonance vibration and noise emission.

N.I.A.E. studies of the contribution of noise from engine surfaces, in which these areas were in turn covered by absorbent foam and lead screening, indicated that these covers did not appear to radiate a significant component of the noise level at the operator position (Table 16.4), although they were more important contributors to bystander noise.

Exhaust noise level is, of course, highly dependent on the efficiency of the silencer. As an example of the influence of silencer efficiency and positioning on operator noise level, Table 16.5 compares four silencer designs, fitted in conventional upright and 'downswept' positions and also in a forward upright position and a 'sideswept' position (Fig. 16.6). Some reduction in noise level is possible, both with or without a cab, by improvement of silencer efficiency or by siting it nearer to the front of the tractor.

Air intake noise may be considerably affected by the design of the air cleaner and intake pipes, and noise reductions near the engine of up to 10 dB have been achieved with side-cavity silencers[13]; however, the siting of air cleaners well away from the operator position makes the inlet noise component generally much less important than that of the exhaust.

N.I.A.E. attempts to reduce engine noise near the source have included a brief assessment of acoustic covers over the engine. Two designs were assessed—(1) a fabricated

**TABLE 16.4**

**Summary of studies of noise from engine surfaces**

Tractor loaded to 85 per cent maximum d.b.h.p. gear nearest 4·5 mile/h.

| Noise source | Contribution dBA at operator position | | Total |
|---|---|---|---|
| Valve gear cover | 83 | | |
| Offside engine wall | 80 | | |
| Inlet manifold and offside of head | 80 | 86 | |
| Exhaust manifold and injector pump | 80 | | |
| Sump | 80 | | |
| | | | 97 |
| Fan and front cowl | 91 | | |
| Inlet | 88 | | |
| Exhaust | 92 | 96·5 | |
| Total other sources, i.e. transmission | 90 | | |

**TABLE 16.5**

**Summary of studies of noise level comparisons with different exhaust system arrangements**

| Silencer | Position | Tractor only dBA | Tractor only Sones | Tractor with standard safety cab dBA | Tractor with standard safety cab Sones |
|---|---|---|---|---|---|
| Standard | Upright | 102·5 | 148 | 100·0 | 128 |
| Improved | Upright | 102·0 | 148 | 97·0 | 102 |
| Standard | Forward | 102·5 | 152 | 96·5 | 95 |
| Improved | Forward | 102·0 | 145 | 96·0 | 87 |
| Standard | Sideswept | 101·5 | 155 | 97·0 | 107 |
| Standard | Downswept | 105·0 | 235 | 98·0 | 130 |

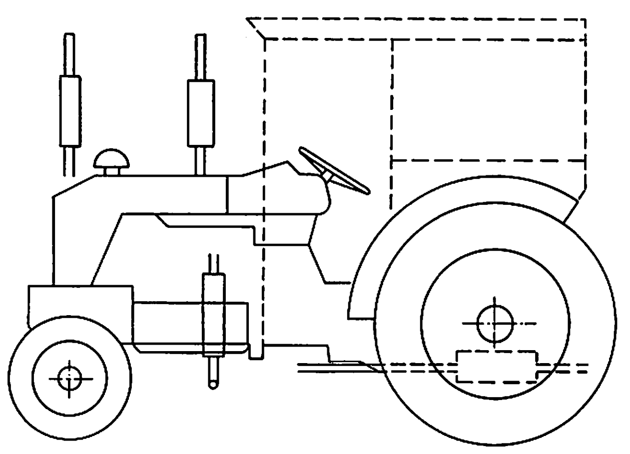


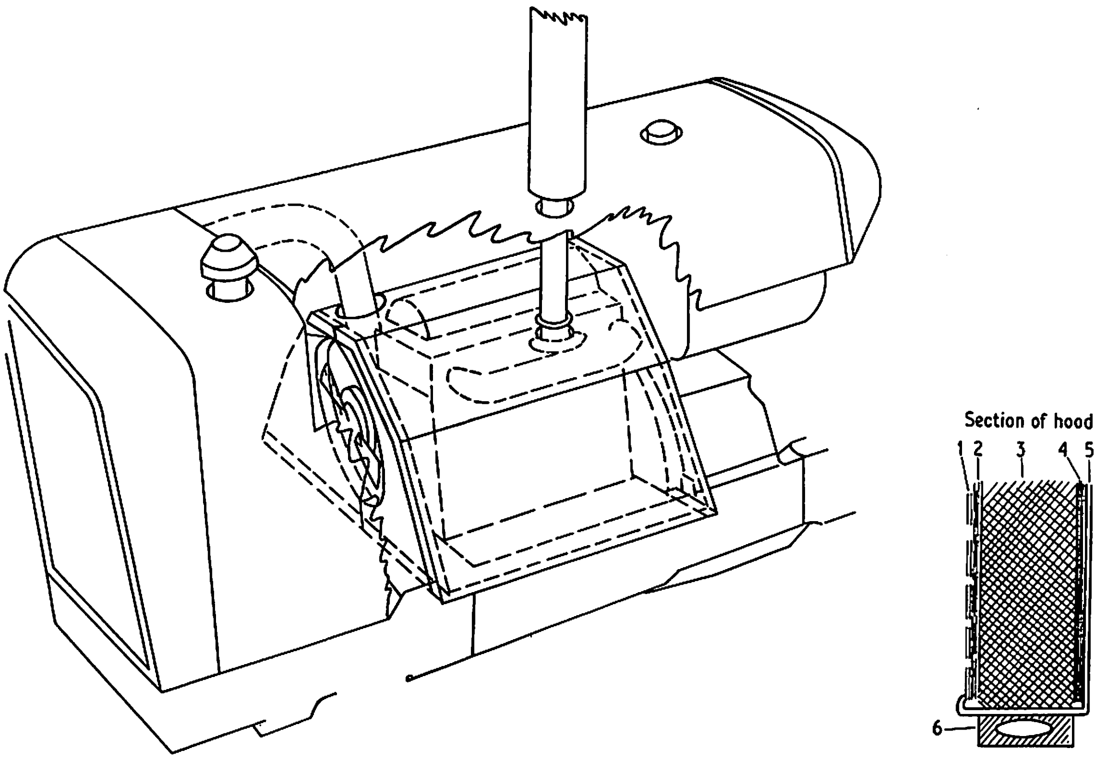
Fig. 16.6. Alternative exhaust and silencer system positions for comparative noise arrangements.

cover of acoustically absorbent mineral wool sandwiched between perforated metal on the inside and a sheet steel outer cover, incorporating convective cooling air paths (Fig. 16.7), and (2) hinged sides to the bonnet of sheet steel lined internally with an absorbent layer. The summarized results (Table 16.6) of tests with the covers fitted to a 65-hp four-cylinder tractor with and without a cab fitted indicate that there is some small reduction of noise at the operator's position, with 'bystander' noise also significantly reduced.

### Noise control by cab design

*Features considered*

From preliminary studies it was concluded that an adequate noise reduction was possible by incorporation of a cab




1. M.S. perforated inner lining.
2. Thermal insulation layer adjacent to exhaust only.
3. Resin bonded acoustic absorber.
4. Panel damping material.
5. 18g m.s. outer panel.
6. Foam neoprene rubber seal.

Fig. 16.7. Schematic diagram of acoustic engine hood.

**TABLE 16.6**

**Summary of influences on operator noise of engine hood and bonnet sides**

| Details | Operator noise dBA | Operator noise Sones | Operator noise NR | By-stander noise, dBA |
|---|---|---|---|---|
| Acoustic hood for engine (no cab) .. .. .. .. | 97 | 100 | 92 | 87 |
| No hood (control) (no cab) .. | 98 | 105 | 94 | 89 |
| Acoustic hood for engine (treated cab) .. .. .. | 93 | 105 | 91 | 87 |
| No hood (control) (treated cab) | 94 | 120 | 96 | 89 |
| Hinged bonnet sides (no cab) .. | 95 | 95 | 93 | 87 |
| No bonnet sides (control) (no cab) .. .. .. .. .. | 98 | 105 | 94 | 89 |
| Hinged bonnet sides (treated cab) .. .. .. .. .. | 88 | 74 | 87 | — |
| No bonnet sides (control) (treated cab) .. .. .. | 90 | 88 | 91 | — |

with adequate attention being given to the design of acoustic features. Fig. 16.8 indicates the progressive reduction of operator noise achieved by acoustic improvements to the cab and, to a lesser extent, to the tractor. These noise reductions were achieved with little attention to the practical convenience or the economics of the measures taken. However, they did assist in defining the potential noise reductions attainable from each measure and compare their effectiveness.

From these results it was decided to concentrate studies on the following aspects of cab design:

(*a*) reduction of vibration and consequent noise generation of the cab structure;

(*b*) elimination of important frame and panel resonances;

(*c*) reduction of air transmitted noise from the engine and transmission into the cab by incorporation of a bulkhead and floor;

(*d*) reduction of noise level within the cab by acoustic absorbent lining;

(*e*) noise reduction by employing fabric materials for cab cladding.

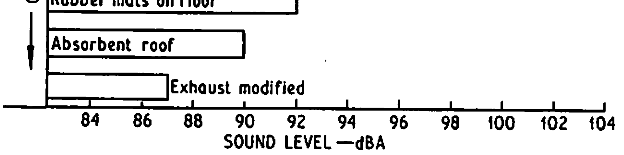
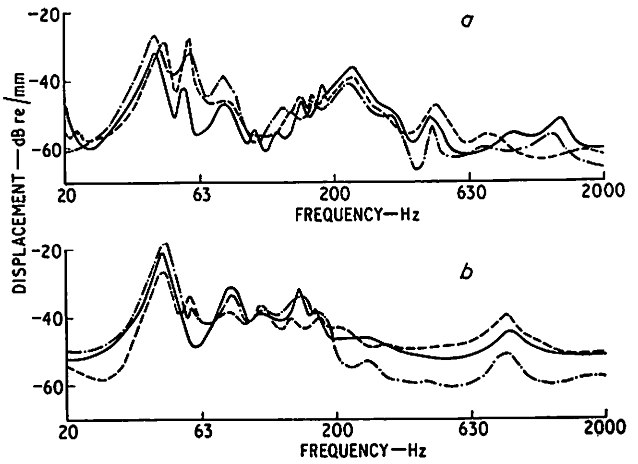



Fig. 16.8. Summary of noise reductions achieved, 52-hp tractor with safety cab.

*Vibration and noise reduction by resilient cab mounts*

It is conventional to mount a safety frame or the main frame of a safety cab on to the rear axle and, in the majority of cases, also on the side of the clutch housing or gearbox. Engine and transmission actions lead to vibration of the mounting positions and with conventional cab design this vibration is transmitted to the cab frame and through it to cab cladding panels. Spectra of vibration on a typical tractor chassis are given in Fig. 16.9. Comparison between spectra recorded with the tractor stationary and with it operating under high draught load suggest that static measurements are sufficiently representative of operating conditions.




(*a*) Front mounting position (*b*) rear mounting position. —·—·— vertical component ——— longitudinal component - - - - - transverse component.

Fig. 16.9. Vibration displacement spectra at cab mounting points, maximum engine speed with tractor stationary.

The relationship between vibration of the cab mountings and consequent cab component vibration and noise generation has been studied by exciting the frame structure with an electromagnetic vibrator (Fig. 16.10). In Fig. 16.11 cab component vibration is related to input vibration mode and frequency where the input vibration amplitude at each frequency (one-third octave intervals) is representative of that recorded on tractors at that frequency. Fig. 16.12 relates increase in noise level at the operator's ear position within the cab to the same series of excitation vibrations of the cab mountings.

These data show the importance of each of the modes of vibration in exciting resonances except that lateral vibration at the front mount, due to high mobility of the structural member in this mode, excites less vibration of other cab components and generates less noise. The presence of several resonances on each cab component due to local and overall structural characteristics is also clear.

Vibration isolating mounts are available in many forms (Fig. 16.13) and may incorporate natural rubber, synthetic foam, or woven wire resilient elements. The common forms of these elements are:

(*a*) rectangular resilient blocks carrying the load in shear through mounting plates and bolts attached to appropriate faces;

(*b*) bushes of resilient material mounted with a vertical axis within a main attachment plate and with the load connected to a vertical central bolt;

(*c*) resilient bushes mounted with a horizontal axis within a main cylindrical shell which incorporates the attachments, with the load carried on a horizontal bolt through the axis of the mount.

Each type of mount offers resilience in all directions., although stiffness and maximum allowable deflection clearly vary between the axial direction and the directions perpendicular to the axis, particularly in the case of the bush mounts. The requirement for the mount to attenuate vibrational components along different axes is shown in Figs 16.11 and 16.12.

A rigorous analysis of the optimum dynamic characteristics of mounts along each axis is difficult since the mobility of the cab structure is complex, particularly in horizontal modes. Moreover, the fixing members and brackets on the tractor may have a significant mobility which affects vibration transmission from the tractor chassis to the cab. Standing wave effects within the resilient components of mounts are significant and have been identified in these studies. These effects can only be determined by measurement of vibration transmission of the mounts over the complete frequency range of interest.

In order to broadly define the characteristics of antivibration mounts used in experiments to assess noise reductions, measurements were made of fundamental stiffness and damping along each of the three principal axes. These data were calculated from the frequency and logarithmic decrement of transient free oscillation excited in the mounts by displacing and releasing weights of 50 and 100 lb appropriately suspended from the mounts. Measured characteristics of the mounts used in the noise reduction assessments are detailed in Table 16.7.

The noise reduction assessment was made by fitting the mounts in turn to a safety cab attached to a 65-hp four-cylinder tractor, noise within the cab being measured with the tractor stationary. Additionally the noise level was measured with the cab rigidly mounted to the tractor and with the cab completely detached from the tractor but supported from the floor to stand over the tractor in the same position as when attached. The majority of mounts led to a reduction of lower frequency noise, the overall effect being much more apparent in loudness data (sones) than where assessed by sound level dBA (Table 16.7). Vibration attenuation achieved by the more effective mounts (Fig. 16.14) can be seen to be good, except for the horizontal modes of vibration at the forward mounts where cab structure mobility is high.

### *Impact performance of resilient mounts*

When employed on a safety cab the mounts must be capable of withstanding (1) the impact to the cab in the event of the tractor overturning, and (2) the static load

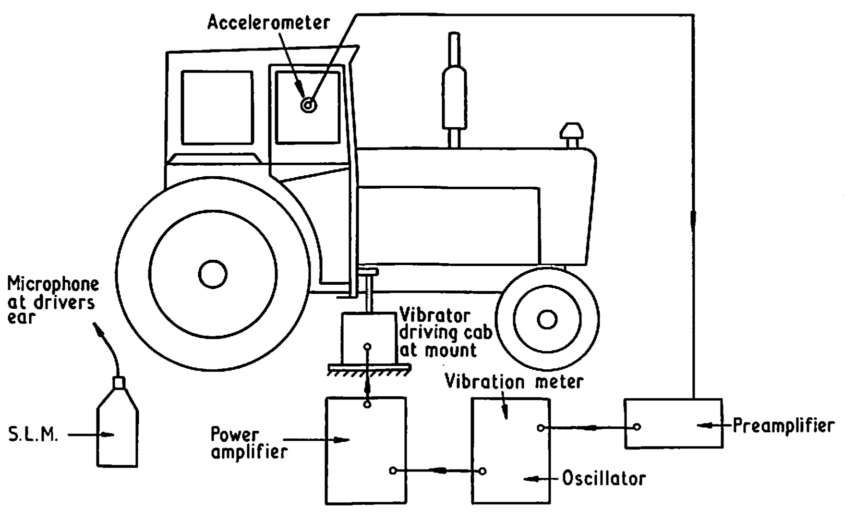



Fig. 16.10. Arrangement for vibration excitation of the tractor cab by electro-magnetic vibrator.

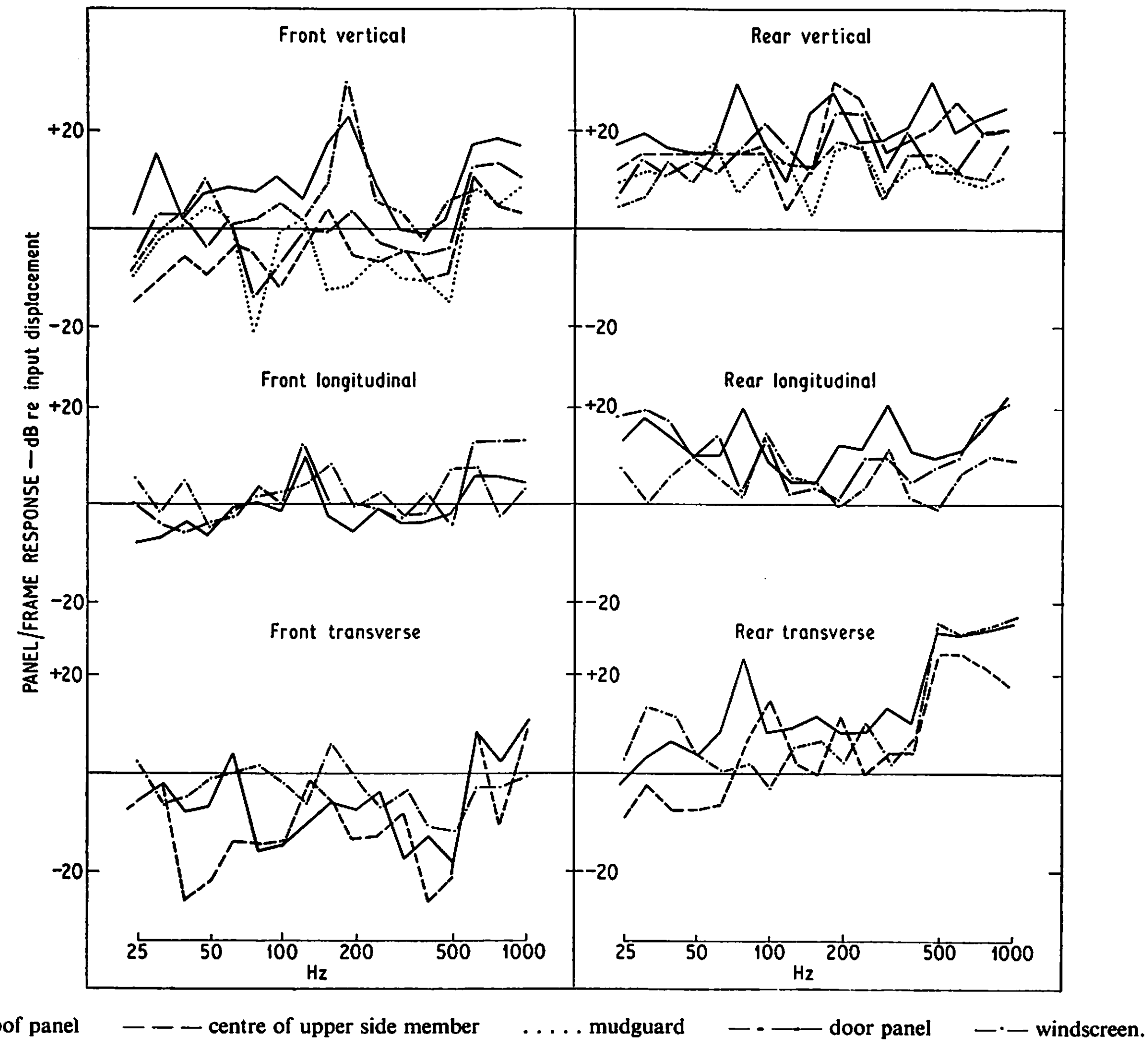



Fig. 16.11. Cab frame component and panel response to vibration excitation of cab.

imposed when the overturned tractor is supported by the structure of the cab. For this purpose it is important that the mounts be incorporated in a way that will allow these impact and static forces to be withstood. With mounts of the types referred to as (*a*) and (*b*) above, this can be achieved by attaching the mounts so that after a large deflection, such as would be caused by a large impacting force, further deflection which might lead to rupture failure of the resilient component is prevented by metal-to-metal contact of 'stops', Examples of mount incorporation structures are given in Fig. 16.15. With the bush type (*c*) there is no need for an external stop since failure of the rubber does not result in the mount parting.

Test impact blows by a pendulum-suspended 4400-lb weight were carried out to the side of a specially strengthened safety frame fitted in turn with six different types of mount. The blow of 7200 lb ft energy was that required by B.S. test for safety cabs[14] for the side impact, bearing in mind the weight of tractor used. The frame was equipped with transducers to measure the deflection amplitude of each mount and the deflection of the frame at the point impacted by the weight. The pendulum weight was fitted with an accelerometer which allowed the impacting force to be determined from the deceleration record, and from this the energy absorbed by frame and mounts to be estimated from force and displacement records.

The only damage sustained by the mounts or fixings during impacts was a fractured $\frac{5}{16}$ in. bolt and bent attachment plates on the mounts. Partly owing to elastic rebound of the weight by the resilient mounts, on average only approximately 35 per cent of the impact energy was absorbed by the mounts and frame during the initial impact blow, compared with 50–90 per cent with rigid mounts.

*Damping of the safety frame structure*

Resonance vibration of safety frames can contribute to the operator's noise level whether fitted with cab cladding or not, and in B.S. tests of frames, noise level increases up to 4 dBA have been measured when the frame alone is fitted. When cladding is added, resonance vibration excitation of panels can also considerably increase noise.

As an alternative to anti-vibration mounts, techniques of increasing the inherent damping of frames may be considered as a means of reducing frame vibration. To study the comparative merits of different damping media, 4-ft lengths of 1·5 in. × 1·5 in. hollow square section steel, as employed in safety frame construction, were filled with sand, wood, semi-rigid expanded polyurethane foam, or concrete. Table 16.8 compares the damping factors calculated from vibration amplitudes at resonance and the noise emitted at resonance, the bar being excited by an electromagnetic vibrator. Clearly the sand filling is the most effective, and its beneficial effect on frame noise was confirmed when a complete safety frame was treated (Table 16.9).

*Cab floor and bulkhead*

To reduce airborne transmission of noise from the engine walls and clutch and transmission casing, a means of noise transmission loss must be introduced between the engine/transmission unit and the operator. A bulkhead at the lower forward walls of the cab can reduce the noise component from engine walls and clutch housing and a fabricated cab floor structure or a flexible covering on the transmission housing can effectively reduce transmission noise in the cab. Both features, provided in different forms and materials, have been assessed and noise reductions achieved are summarized in Table 16.10.

**TABLE 16.7**

**Summary of performance of anti-vibration mounts**

| | Stiffness, lb/ft × 100 | | Damping ratio, × 10⁻³ | | Vibration r.m.s. displacement attenuation, dB Front | | | Rear | | | Impact energy absorbed in initial blow | Noise influence in relation to rigid mounts, untreated cab | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mount type | Axial | Radial | Axial | Radial | L | T | V | L | T | V | per cent | dBA | Sones |
| (1) Rubber bonded compression mount, 35 shear rubber | 105–130 | 60–70 | 18–22 | 18–30 | 15 | −1 | 18 | 16 | 9 | 17 | 35 | +1·2 | −15 |
| (2) Conical rubber compression/shear mount with limit stops | 90–100 | 160–190 | 16–26 | 10–16 | 11 | 1 | 22 | 12 | 8 | 14 | 36 | −0·2 | −17 |
| (3) Double rubber bush with integral springs* | 270–300 | 240–450 | 22–34 | 13–30 | 10 | 1 | 19 | 15 | 14 | 10 | 36 | 0 | −21 |
| (4) Washer type with microcellular rubber/urethane* | 280–320 | 290–420 | 35–47 | 20–25 | 12 | 2 | 18 | 12 | 7 | 11 | 38 | +0·4 | −29 |
| (5) As (1) but 55 shear rubber | 190–235 | 120–190 | 20–47 | 23–53 | 12 | 0 | 18 | 18 | 8 | 8 | Not tested | −0·4 | −31 |
| (6) Rubber shear mount, very robust construction | 145–165 | 80–160 | 48–58 | 25–46 | 9 | 0 | 16 | 10 | 2 | 6 | Not tested | −0·2 | −31 |
| (7) Eccentric rubber bush, 35 shear rubber | 37–110 | 85–94 | 70–120 | 16–20 | Not recorded | | | Not recorded | | | Not recorded | −0·2 | −33 |
| (8) Rubber washer type with limit stops* | 840–930 | 230–250 | 30–35 | 18–30 | Not recorded | | | Not recorded | | | Not recorded | −0·5 | −33 |

*Mount pretensioned. L = Longitudinal. T = Transverse. V = Vertical,
*Note.* The fully isolated cab with no mechanical contact with the tractor gave reductions in relation to the rigid mounting of 1·2 dBA, 46 sones.

**TABLE 16.8**

**Summary of resonance studies on hollow-section steel with various damper fillings**

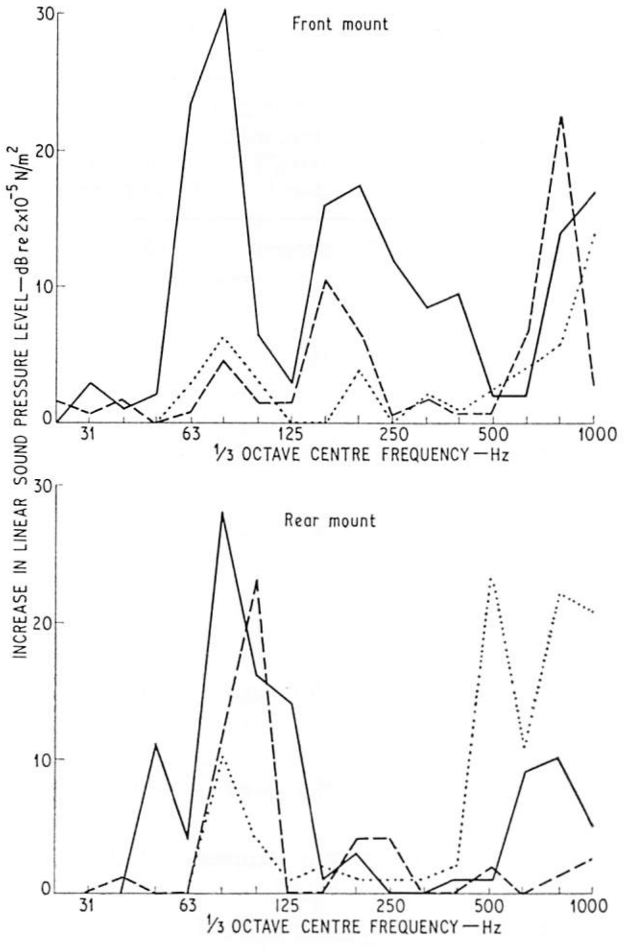
| | First resonance | | Second resonance | | Third resonance | |
|---|---|---|---|---|---|---|
| Damping treatment | Damping factor | Noise* | Damping factor | Noise* | Damping factor | Noise* |
| Nil | 0·03 | 21 | 0·01 | 22 | — | 28 |
| Wood | 0·04 | 16 | 0·03 | 20 | — | 29 |
| Polyurethane foam | 0·06 | 18 | 0·01 | 20 | — | 24 |
| Concrete | 0·05 | 15 | 0·02 | 12 | — | 25 |
| Sand | 0·5 | 10 | — | — | — | 14 |

*Noise level near section at resonance in dBA above background level.

**TABLE 16.9**

**Effect on operator noise level of a sand filling of the safety frame to damp resonances**

| Detail | Operating conditions | dBA | Sones | NR |
|---|---|---|---|---|
| Tractor only (no frame fitted) | Fourth gear | 94·5 | 90 | 91 |
| Normal frame | 2750-lb drawbar load | 96·5 | 110 | 95 |
| Sand-filled frame | | 95·5 | 95 | 92 |
| Tractor only (no frame fitted) | Fourth gear | 95·5 | 95 | 92 |
| Normal frame | 3500-lb drawbar load | 98·5 | 120 | 96 |
| Sand-filled frame | | 96·0 | 100 | 93 |




—— vertical input mode– – – –longitudinal- - - - - -transverse.

Fig. 16.12. Relationship between noise level generated within a typical cab and cab excitation vibration.

The bulkhead may clearly be a rigid structure of sheet metal or fibreglass sheet (provided adequate weight and damping are present), or may be a flexible cladding of heavy fabric perhaps treated with a mastic to increase transmission loss. The latter may be more easily incorporated in an existing design of tractor and cab. Some transmission loss data measured on suitable rigid panel materials and on fabric combinations are given in Fig. 16.16.

Floors are difficult to add to existing tractor designs due to the need for controls to protrude adequately through them. However, a combined floor/bulkhead unit fabricated from sheet steel has been satisfactorily added to a current production model of tractor (Fig. 16.17) with worthwhile noise reduction (Fig 16.18). A moulded or fabricated close-fitting covering for the transmission housing, made of heavy rubber, plastic, felt, or a combination of these materials may be acoustically effective. However, its applicability must depend on the acceptability of the consequent reduction in heat loss from the casing.

**TABLE 16.10**

**Summary of noise reductions achieved by incorporating bulkhead and floors in a cab**

| Item incorporated | Noise reduction dBA | Sones | NR |
|---|---|---|---|
| Felt/p.v.c. bulkhead cover (cab with absorbent lining) .. .. .. .. | 3·5 | 35 | 3·5 |
| Felt/canvas bulkhead cover (standard cab) .. .. .. .. .. | 2·0 | 15 | 1·5 |
| Felt/canvas bulkhead cover (cab with absorbent lining) .. .. .. | 2·0 | 5 | 2·0 |
| Felt/rubber floor covering (treated cab) | 5·0 | 25 | 3·0 |
| Felt/rubber bulkhead and floor cover (cab with absorbent lining) .. .. | 5·0 | 5 | 2·0 |
| Sheet steel bulkhead and floor (cab with absorbent lining) .. .. .. | 4·5 | 50 | 9·0 |
| Sheet steel bulkhead and floor (untreated cab) .. .. .. .. .. | 4·0 | 30 | 3·0 |

*Acoustically absorbent linings*

In addition to generating noise from panel and frame vibration, an unlined metal and glass cab provides an enclosure which, even when occupied by the tractor driver, has a relatively long reverberation time and in which noise can accumulate such that the reverberant component considerably exceeds that due to direct airborne transmission from the sources. Early experiments indicated that a significant noise reduction could be achieved by lining internal cab surfaces—including the roof, side (mudguard) panels, door panels, and bulkhead—with acoustically absorbent materials. Several types of material

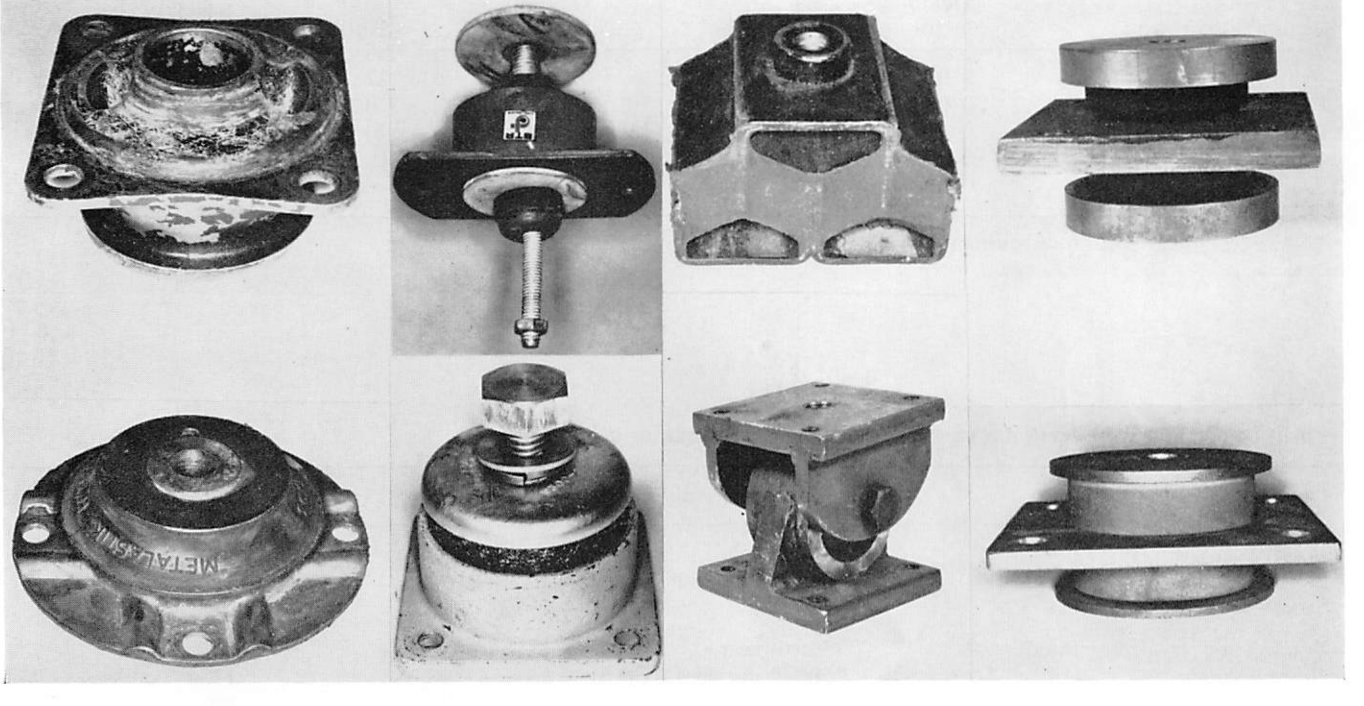


Fig. 16.13. Resilient mounts studied for attachment of tractor safety cabs.

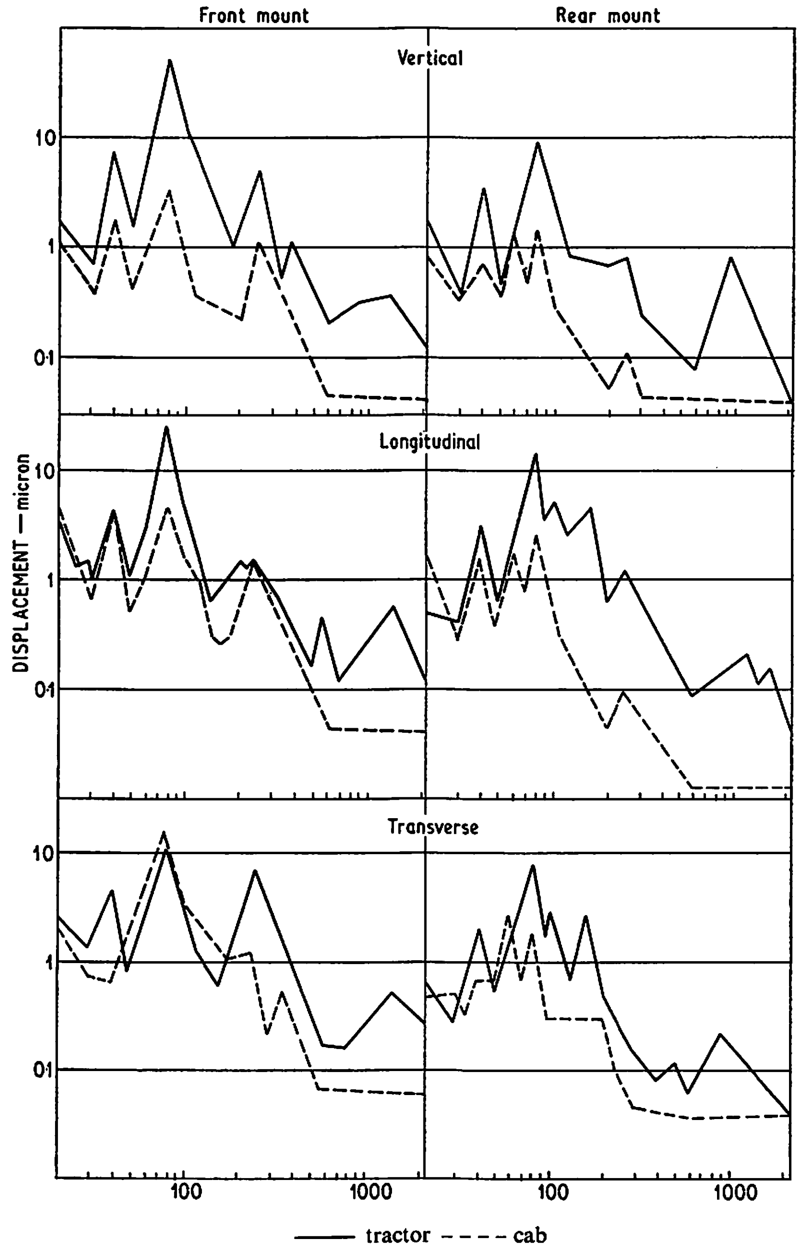



Fig. 16.14. Comparison of vibration spectra on either side of resilient mounts.

with a valuable absorption are available, including felts, mineral wools, and open cell plastic foams[15]. Not all available materials would be considered sufficiently durable for this application, particularly at the lower regions of the cab where mud, scraping boots, and spilt fuel or oil might all be hazards. In the case of mineral wools, covering is considered necessary to retain the wool in position.

Acoustic absorption may be effected by two processes: transmission of the sound through connected pores or inter-fibrous gaps of porous materials with consequent dissipation of energy and multiple reflection, or excitation of surfaces into resonance vibration with subsequent loss of energy in the air space or absorbent space behind the surface. The absorption of many materials has been reported, and general guidance is available for their employment[16].

Fig. 16.19 summarizes measurements of acoustic absorbency of likely materials for cab lining. From these data the following may be observed:

(*a*) Materials of increasing thickness offer significantly improved absorption over thinner samples.

(*b*) The covering of mineral wool linings by perforated metal or hardboard does not reduce absorption significantly, providing the perforations of an open area of not less than 5 per cent of the total.

(*c*) The frequency of maximum effectiveness may be reduced by covering the absorbent with a thin skin, but both the maximum absorption and the absorption at higher frequencies will be reduced.

(*d*) Absorption at the important frequency range on the tractor of 500–1000 Hz may be good, but little absorption can be expected at the lower frequency range below 125 Hz, corresponding with the engine firing frequency.

Although indicating more effective materials and likely frequency ranges in which noise reductions can be expected, these measurements cannot easily be used to forecast the magnitude of noise reduction expected by treatment of a tractor cab or the area of lining beyond which no further significant reduction would be achieved. The simple theory of enclosure absorption, after Sabine, assumes a uniform diverse sound field within the enclosure. That this is not so in a tractor cab is clear from Fig. 16.20, which shows noise contours within a typical acoustically treated (lined) cab. However, knowledge of noise contours within the cab does allow absorbent linings to be sited at regions of high sound level where they will be more effective. A given area of absorbent sited below the seat level (Fig. 16.20), where the noise level is 87–88 dBA, should in general be approximately as effective as an absorbent of twice the area sited in the roof, where the sound level is 3 dBA less.

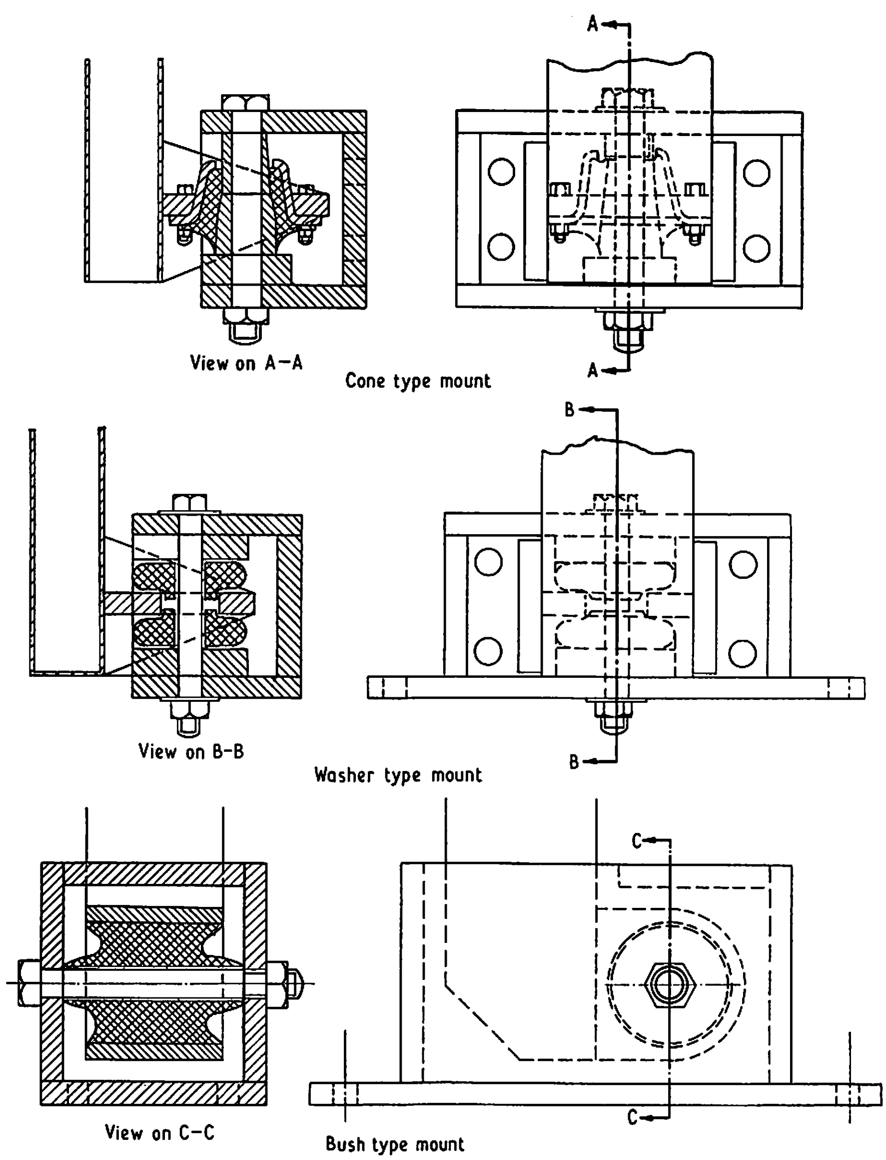
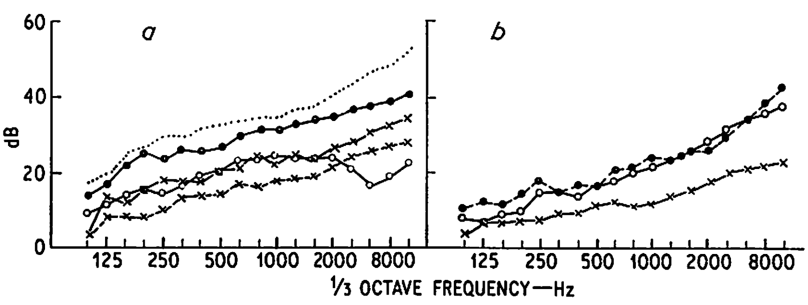



Fig. 16.15. Diagram of some means of incorporating resilient mounts.




| | | | |
|---|---|---|---|
| *a*) Rigid materials | ●———● | 19g m.s. | 1·7 lb ft² |
| | .......... | 19g m.s. plus barrier mat | 3·7 lb ft² |
| | o———o | 9 mm plywood | 1·1 lb ft² |
| | ×———× | glass reinforced plastic | 0·92 lb ft² |
| | × – – × | glass reinforced plastic | 0·37 lb ft² |
| (*b*) Fabric materials | ●———● | canvas/felt/canvas | 0·82 lb ft² |
| | o———o | felt with p.v.c. coating | 0·6 lb ft² |
| | ×———× | P.v.c. coated canvas | 0·17 lb ft² |

Fig. 16.16. Transmission loss of some materials for cab bulkhead construction.

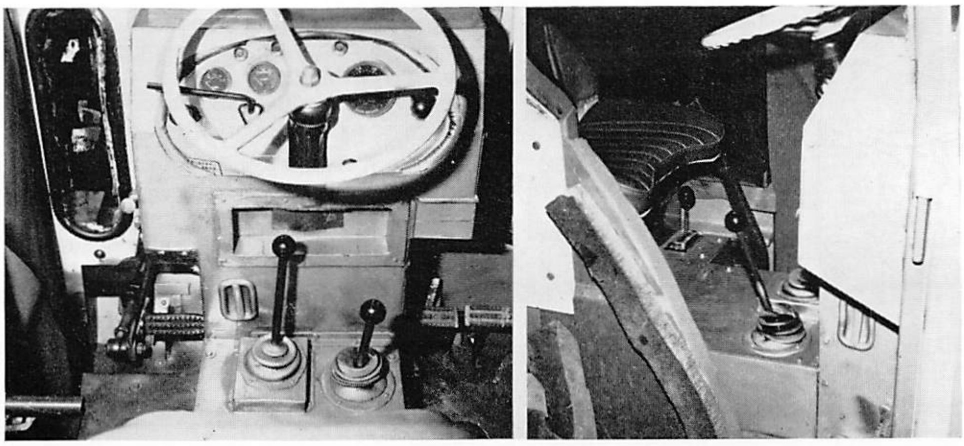
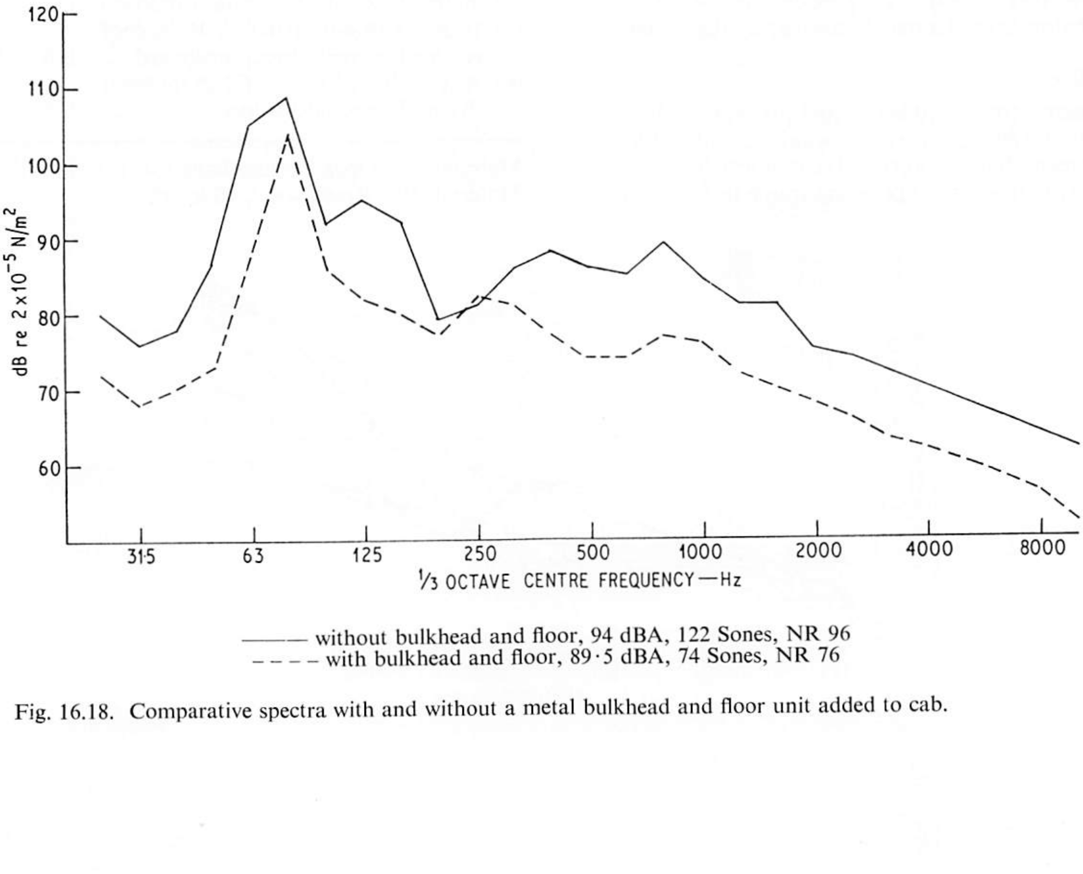


Fig. 16.17. Combined sheet steel bulkhead for floor and cab.




——— without bulkhead and floor, 94 dBA, 122 Sones, NR 96
– – – – with bulkhead and floor, 89·5 dBA, 74 Sones, NR 76

Fig. 16.18. Comparative spectra with and without a metal bulkhead and floor unit added to cab.

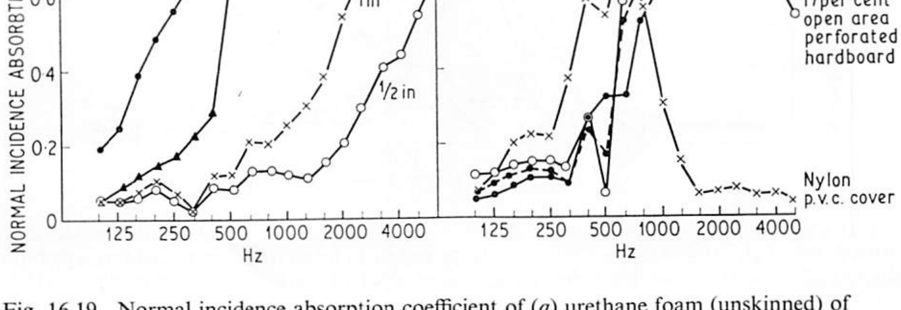



Fig. 16.19. Normal incidence absorption coefficient of (*a*) urethane foam (unskinned) of various thicknesses (*b*) mineral wool (1 in thick) with various covers.

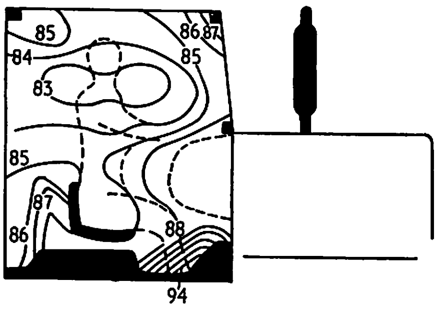



Fig. 16.20. Noise (dBA) contours inside an acoustically designed cab; tractor stationary at maximum engine speed

The reduction in noise level by different linings has been measured on representative cabs and also with and without floor and bulkhead and anti-vibration mounts (Table 16.11). Typical spectra are shown in Fig. 16.21*a*. In general, these spectra confirm the forecast of greater attenuation of high-frequency noise than low-frequency noise. When compared with estimates of reduction made by the Sabine theory, the magnitude of the noise reduction also suggests that in addition to noise reduction by absorption, further reduction is being effected by a decrease in noise emission from the panels covered by the lining.

*Fabric cladding*

There has been a considerable demand for fabric cab cladding with flexible side and rear windows and a solid glass windscreen. Such a fabric cab can normally be removed quickly from the supporting frame in fair weather, is generally less prone to noise and drumming, and is less expensive. With the legal requirements for safety frames it is considered that fabric cladding could still be attractive to many users who would at some times of the year remove the cover to use a safety frame only.

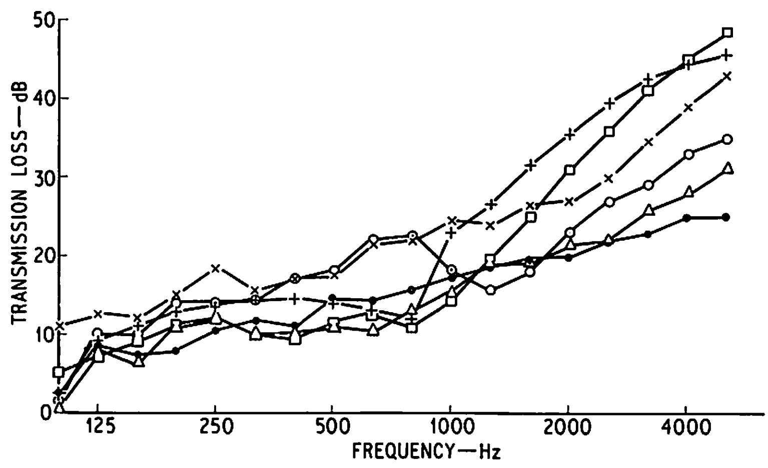
With such cladding optimum noise reduction could be achieved by employing a material or combination of materials with a high noise transmission loss and a high acoustic absorbency on the internal surface

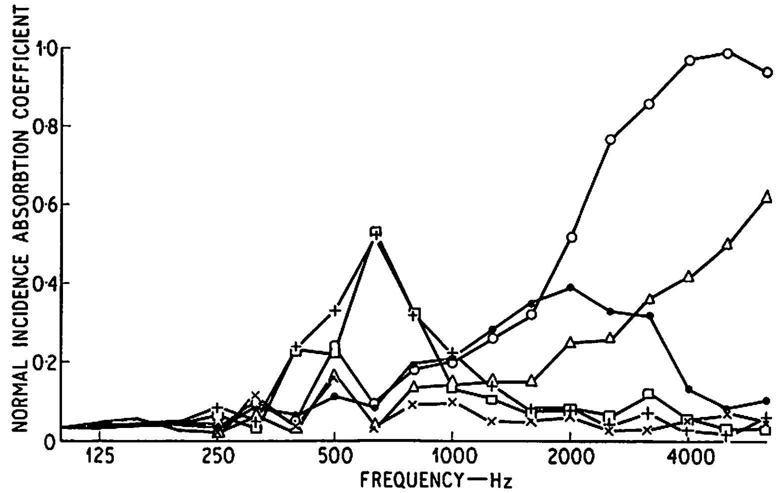
**TABLE 16.11**

**Summary of noise reductions achieved by lining cabs with acoustic absorbent material**

| Treatment | Typical reduction dBA | Sones | NR |
|---|---|---|---|
| (1) 16 sq. ft of 2-in material 'A' in roof .. | 3·5 | 15 | 4·5 |
| (2) 16 sq. ft of 4-in material 'A' in roof | 4·0 | 27 | 6·5 |
| (3) As (2) plus 16 sq. ft of 1·5-in material 'A' doors and fenders .. .. | 5·5 | 26 | 6·5 |
| (4) As (3) plus further 30 sq. ft of 2-in material 'A' (includes side windows) | 11·5 | 40 | 11·5 |
| (5) 16 sq. ft of 4-in material 'B' in roof retained by perforated hardboard | 1·0 | 11 | 2·0 |
| (6) As (5) plus 12 sq. ft of 2-in material 'B' on doors and fenders .. .. | 5·5 | 30 | 8·0 |

Material 'A'; Open cell urethane foam, 1·8 lb/ft³.
Material 'B'; 'Rock wool', 10 lb/ft³.

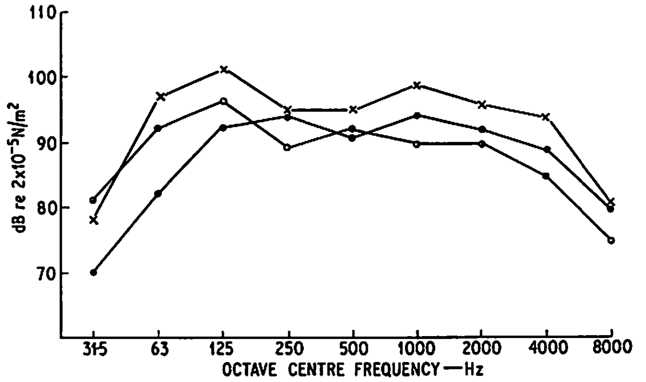



● p.v.c. coated cotton duck with 0·25 in acoustic foam.
○ proofed cotton duck with 0·5 in high density foam.
+ p.v.c. coated cotton duck/0·375 in cotton wadding/nylon p.v.c.
× proofed cotton duck/0·5 in jute felt/proofed cotton duck.
□ proofed cotton duck/wool wadding/nylon p.v.c.
△ proofed cotton duck/wool wadding.

Fig. 16.21. Transmission loss and absorption data of fabric cab materials.

These characteristics have been assessed on different material combinations (Fig. 16.21*a* and *b*), using cotton and plastic sheet already employed for cab construction together with layers of other material. From these data a combination consisting of a proofed cotton duck external layer, 0·5-in. jute felt and lined internally with a thin nylon p.v.c. sheet was chosen and cladding was constructed so that its noise properties could be assessed on a tractor (70 hp) fitted with a standard safety frame. A significant reduction of noise from the level with normal cladding was achieved (Fig. 16.22).




●——● frame only, 98 dBA, 110 Sones, NR 94.
×——× typical cover, 103 dBA, 165 Sones, NR 99.
o——o improved cladding, 97·5 dBA, 96 Sones, NR 90.

Fig. 16.22. Comparative spectra with and without experimental fabric cladding

**Summary of noise reduction measures on a typical metal cladded safety cab**

To summarize the effects of important noise reduction measures on a metal cab, Fig. 16.23 shows the reductions achieved by the following measures on a cab fitted to a 65-hp tractor:

(*a*) floor and bulkhead incorporation;
(*b*) acoustic absorbent lining;
(*c*) anti-vibration mounts;
(*d*) bonnet treatment with a fabric layer to improve transmission loss and noise absorption.

The noise reduction achieved by these improvements was 12 dBA, 85 sones, or NR11.

## Summary

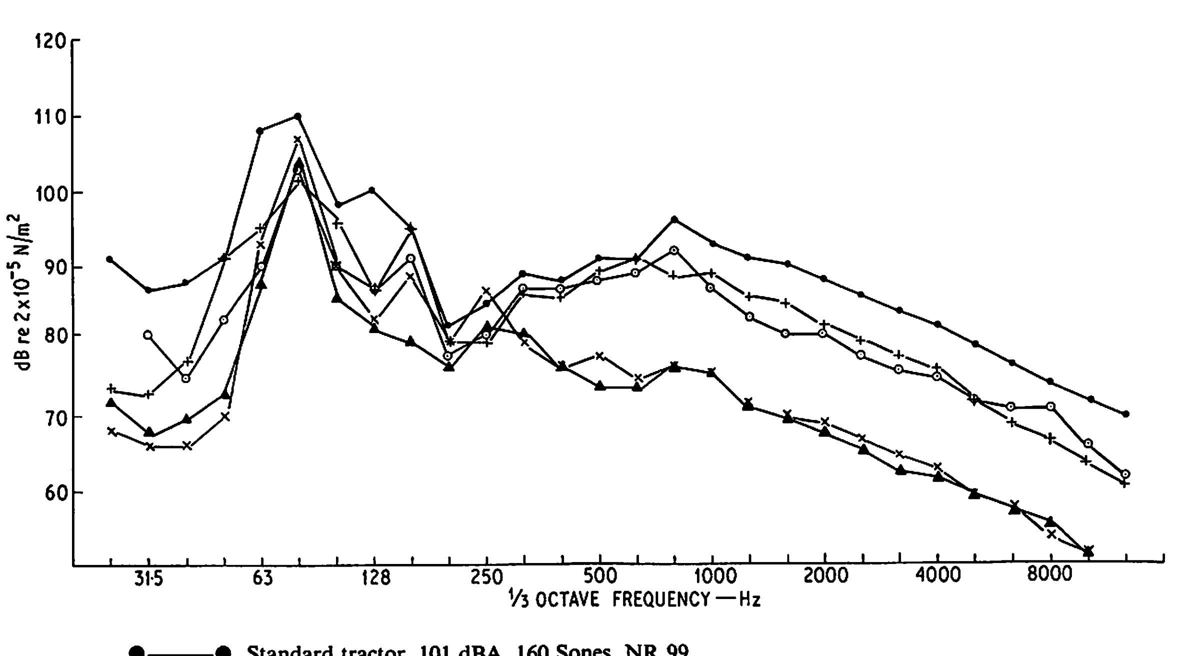
A high incidence of noise-induced hearing loss is evident from audiological surveys of tractor drivers. There is also considerable evidence that drivers frequently restrict the speed of work due to their unwillingness to be subjected to the very high noise levels arising when the tractor is operated at maximum power. The increased use of cabs on tractors, particularly structurally robust cabs of resisting crushing if the vehicle overturns, has led to a further increase in the noise level of the operator's environment and to levels at maximum power of 95–110 dBA. In addition to noise from the engine and transmission a large component is generated by the cab framework which is conventionally rigidly attached to the clutch housing and rear axle and by the cab cladding panels.

Without a cab the exhaust noise is normally predominant, noise levels varying much more with engine speed than with load, while transmission noise is an important and rather variable additional component.

Studies have indicated that a noise level reduction to 90 dBA is possible by modifications to the design of cabs, while some reductions may be achieved by acoustic covers to the engine, by improvements in the design or siting of the exhaust and silencer system, or, in the future, by radical modifications to the design of the engine and transmission structure.

The inclusion of resilient elements in the attachments of the cab significantly reduces lower frequency noise and has been shown to maintain adequate strength to withstand impacts to the structure in an impact resistance test which simulates vehicle overturning. As an alternative means of attenuating structural vibration, particularly where a safety framework alone is employed, a sand filling of hollow structural members has been shown to be effective.

Airborne noise, particularly from the walls of the engine and from the transmission, may be attenuated by a substantial bulkhead and floor to the cab. Both rigid and fabric designs of bulkhead have been assessed and a combined fabricated metal bulkhead/floor unit has shown to effect a 5 to 6 dBA reduction in cab noise level.




●——● Standard tractor, 101 dBA, 160 Sones, NR 99.
+——+ Anti vibration mounts, 99 dBA, 130 Sones, NR 97.
o——o Sheet metal bulkhead and floor, 95 dBA, 100 Sones, NR 94.
×——× Absorber in roof and on doors and mudguards, 90 dBA, 88 Sones, NR 91.
△——△ Bonnet treatments, 89 dBA, 74 Sones, NR 87·5.

Fig. 16.23. Spectra from progressive noise reduction treatment to a 65-hp tractor with metal cladded safety cab.

Acoustically absorbent linings to the cab roof, side walls, and doors reduce reverberant noise and may also effect a reduction of up to 5 dBA. Studies have been made of linings of plastic foam and mineral wool, various coverings for the latter, to improve durability being included.

Where the tractor is fitted with a safety frame only, a low noise fabric cladding is proposed. One version has been constructed from a fabric combination with a proofed cotton duck external layer, felt inside this, and an internal thin lining of nylon p.v.c.—the combination exhibiting relatively high transmission loss and good acoustic absorption internally.

## Conclusions

1. Current noise levels to which tractor operators are subjected are unsatisfactory, probably leading to physiological damage and decreased operating efficiency.
2. There is a prospect of reductions in noise by modification to engine design, but it is improbable that these measures alone can lead to entirely satisfactory levels.
3. The cab, although currently in most cases causing an increase in operator's noise, can be the means of achieving large and probably sufficient noise reductions.
4. Noise generated by vibration excitation of the cab structure can be reduced by incorporating resilient components in the structure attachment to the vehicle.
5. Air-transmitted noise from the engine or transmission housing may be attenuated by the incorporation in the cab of a suitable floor and bulkhead.
6. Acoustically absorbent linings are effective and may be of several forms.
7. A fabric cladding made of a suitable material 'sandwich' with high transmission loss and high internal acoustic absorbency can produce a worthwhile noise reduction.

From these studies it may be concluded that if acceptably low noise levels are to be achieved on the tractor, no one measure is sufficient but the approach must be on the basis of a number of acoustic improvements.

## Acknowledgements

The authors wish to record their appreciation to colleagues whose experimental work is discussed in the paper; particularly to R. W. Tomlinson, R. M. Stayner, D. W. Evernden, A. H. Hakimi and G. Pearson. Appreciation is also expressed for the loan of tractors and cabs, particularly to Ford Motor Co., David Brown Tractors, Massey-Ferguson Ltd. Alexander Duncan Ltd, and Stadri Ltd.

## Appendix 16.1

**The effect of microphone position on noise measurement**

*Summary of studies made*

Studies have included comparisons of the following microphone positioning and other variations:

(*a*) mounting to the left-hand and right-hand side of the head, and the relationship to the side on which the exhaust outlet is sited;
(*b*) inclination of the head by the operator while carrying the microphone;
(*c*) positioning of the microphone in relation to the side of the head and, in particular, the ear;
(*d*) standard and omni-directional microphone covers.

In most cases comparisons were made on tractors with and without cabs, and in some instances with more than one operator. Except where positioning on both sides of the head was compared, all studies were made with the microphone on the left-hand side of the head, on which side the tractor exhaust was also sited.

**TABLE 16.12**

**Summary of comparisons of variations in microphone positioning and covers**

| Position or cover detail | Mean noise level reading dBA | Sones | Differences dBA | Sones |
|---|---|---|---|---|
| Microphone left side, no cab | 94·5 | 110 | | |
| Microphone right side, no cab | 95·0 | 105 | +0·5 | −5 |
| Microphone left side, cab | 99·5 | 160 | | |
| Microphone right side, cab | 97·0 | 155 | −2·5 | −5 |
| Head forward .. .. | 97·0 | 125 | | |
| Head 20° to left .. .. | 96·0 | 115 | −1·0 | −10 |
| Head 20° to right .. .. | 95·5 | 110 | −1·5 | −15 |
| Standard microphone position | 102·0 | 170 | | |
| Position A .. .. .. | 101·5 | 155 | −0·5 | −15 |
| Standard microphone position | 96·5 | 120 | | |
| Position B .. .. .. | 99·0 | 145 | +2·5 | +25 |
| Position C .. .. .. | 97·5 | 125 | +1·0 | +5 |
| Standard microphone cover | 97·0 | 125 | | |
| Omni-directional microphone cover .. .. .. | 96·5 | 120 | −0·5 | −5 |

*Microphone positions:*

Standard—In line with forehead and 5 cm from temple;
A —Approximately 2·5 cm from auricular point;
B —Close to auricular point and in contact with concha;
C —In line with forehead and in contact with temple.

*Results of studies*

On some tractors there appears to be a significant difference between noise levels on either side of the operator's head. Examples only are given in Table 16.12, but in all cases where a difference has been observed, the higher level is on the side nearest to the exhaust outlet.

Inclination of the head by the operator while measurements are being made through a microphone attached to his head can lead to errors and must be avoided.

The measurements appear to be affected by microphone positioning in relation to the side of the head, particularly when the microphone is very close to the head.

**TABLE 16.13**

**Comparison of operator noise levels (55-hp tractor without cab) measured in anechoic bale chamber and free field conditions**

| Condition | Engine speed, rev/min: 750 (min. speed) dBA | Sones | 1200 dBA | Sones | 1600 dBA | Sones | 2000 dBA | Sones | 2550 (max. speed) dBA | Sones |
|---|---|---|---|---|---|---|---|---|---|---|
| Free field (wind noise level=40–45 dBA) | 78 | 35 | 83 | 45 | 85 | 60 | 90 | 75 | 94 | 100 |
| Anechoic chamber of straw bales | 78 | 35 | 82 | 45 | 85 | 60 | 91 | 80 | 93 | 100 |

Little significant difference was observed in these and other studies between the standard protecting grid microphone cover and the omni-directional cover (Bruel and Kjaer No. UA 0055) (Table 16.12).

**Measurements of noise levels with the tractor stationary**

*Anechoic chamber*

For a stationary tractor or other equipment which can be fitted into a similar space, it has been found practicable to construct an enclosure of straw bales which, being totally enclosed, eliminates wind noise and considerably reduces ambient noise generated by nearby machinery. The data in Table 16.13 show the straw bale enclosure to be quite satisfactory as an anechoic chamber, providing free field conditions.

*Effect of presence of an operator*

Provided that the presence of an operator's head and body does not affect the noise level it is obviously an advantage when making measurements with a stationary vehicle to be able to dispense with the operator.

Comparative measurements were made of noise levels (*a*) with the microphone attached to the headgear worn by an operator, (*b*) with the headgear fitted on a simulated head (inflated rubber bladder) in the same position as the operator's head, and (*c*) with the microphone suspended freely in the same position. From these measurements, summarized in Table 16.14, the operator's presence does not appear to affect the noise levels measured on a tractor without cab.

**TABLE 16.14**

**Effect of the operator's presence on measurements of noise at operator's ear position in a tractor without cab**

| | Engine speed, rev/min | | | |
|---|---|---|---|---|
| | 1200 | | 2550 | |
| Condition | dBA | Sones | dBA | Sones |
| Actual operator with microphone on head gear .. .. .. | 82 | 45 | 94 | 105 |
| Artificial head with microphone on head gear .. .. .. | 83 | 45 | 93 | 100 |
| Microphone suspended in head position. No operator .. .. | 82 | 45 | 94 | 100 |

**Factors affecting the accuracy of measurement**

*Wind*

Particularly where the tractor has no cab, the factor which most frequently limits the accuracy of the measurement is the wind. Wind noise appears principally as low-frequency components (40–100 Hz).

Noise measurements are normally carried out only when the wind noise level, as indicated by the sound level meter switched to the LINEAR and A-WEIGHTING positions, is at least 10 dB below the respective linear and A-weighting levels of the noise to be measured. A special microphone cover may be fitted to reduce wind noise, in which case the 10dB differenetial must be achieved with this cover fitted.

*Presence of loading car*

Draught loads on the tractor during measurement of noise are normally provided by a hydraulic load vehicle. There are two potential sources of error in the noise measurement arising from this machine: contributions from noise generated by the vehicle and reflections of tractor generated noise from the front of the loading vehicle.

For noise measurements the loading car is towed by a length of chain, so that a distance of at least 20 ft is maintained between the tractor operator and the front of the vehicle. Under these conditions, presence of the vehicle was shown to have an insignificant effect on the noise level at the tractor operator.

*Effect of ground surface*

Comparative measurements made on tractors with and without cabs operating over tarmacadam, unmetalled track, and grass surfaces (Table 16.15), showed that there is no significant effect of the surface on the sound level (dBA) or sones at the operator's ear position.

*Effect of size of operator*

Table 16.16 outlines comparative measurements of sound level with operators of 64–74-in. stature. There is no evidence of a significant effect due to the size of the operator.

*Effect of operator dress*

Table 16.17 shows that this factor apparently has no significant effect on the noise at the operator's ear position. 'Normal clothing' was jacket and trousers; 'heavy clothing' consisted in addition of overcoat, wool scarf, and wool hat; and 'light clothing' consisted of boiler suit without jacket.

*Variability of measurements*

The accuracy of measurement of dBA and loudness in sones may be assessed from the variability of five series of eight independent determinations made of these data with five different conditions of tractor operation (tractors with and without cabs). In each case the eight measurements were spread over two days.

From these data (Table 16.18) it will be seen that the 19/20 limits of dBA measurement are estimated as $\pm 1 \cdot 5$ dB and those of the loudness in sones as $\pm 10$ sones (19/20 limits $= \pm 2 \times$ standard deviation).

**TABLE 16.15**

**The effect of ground surface on noise level at ear position of operator**

| | | | Tarmacadam | | Grass | | Unmetalled track | |
|---|---|---|---|---|---|---|---|---|
| Tractor details | Gear | Load, lb | dBA | Sones | dBA | Sones | dBA | Sones |
| 55-hp without cab | Fourth | 2900 | 88 | 65 | 87 | 75 | — | — |
| | Sixth | 2300 | 88 | 70 | 89 | 75 | — | — |
| 65-hp with cab | Fourth | 3000 | 97 | 115 | 97 | 115 | — | — |
| | Sixth | 2000 | 97 | 130 | 97 | 115 | — | — |
| 55-hp without cab | Fifth | Nil | 94 | 95 | 95 | 95 | 95 | 100 |
| 55-hp with cab | Fourth | Nil | 96 | 105 | 97 | 110 | 96 | 110 |

**TABLE 16.16**

**The effect of the size of operator on noise level at ear position of operator**

| | | | Small operator (64 in) | | Average operator (69 in) | | Large operator (74 in) | |
|---|---|---|---|---|---|---|---|---|
| Tractor details | Gear | Load, lb | dBA | Sones | dBA | Sones | dBA | Sones |
| 55-hp without cab | Second | 3400 | 96 | 130 | 95 | 115 | 96 | 130 |
| | Fourth | 2900 | 95 | 110 | 95 | 105 | 95 | 110 |
| | Sixth | 2300 | 95 | 103 | 96 | 110 | 95 | 110 |
| 65-hp with cab | Third | 3800 | 96 | 110 | 97 | 110 | 97 | 125 |
| | Fourth | 3000 | 97 | 120 | 98 | 115 | 97 | 110 |
| | Sixth | 2000 | 96 | 120 | 97 | 115 | 96 | 110 |

**TABLE 16.17**

**The effect of operator dress on noise level at ear position of operator**

| | | | Normal clothing | | Heavy clothing | | Light clothing | |
|---|---|---|---|---|---|---|---|---|
| Tractor details | Gear | Load, lb | dBA | Sones | dBA | Sones | dBA | Sones |
| 55-hp without cab | Second | 3400 | 95 | 115 | 95 | 125 | — | — |
| | Fourth | 2900 | 95 | 105 | 95 | 110 | — | — |
| | Sixth | 2300 | 96 | 110 | 96 | 115 | — | — |
| 65-hp with cab | Third | 3850 | 97 | 110 | 96 | 105 | — | — |
| | Fourth | 3000 | 98 | 110 | 97 | 110 | — | — |
| | Sixth | 2000 | 97 | 115 | 97 | 110 | — | — |
| 55-hp without cab | Sixth | Nil | 95 | 100 | — | — | 95 | 95 |
| 55-hp with cab | Sixth | Nil | 96 | 110 | — | — | 97 | 105 |

**TABLE 16.18**

**Variability of noise levels at ear position of operator**

| Tractor details | No. of measurements | Standard deviation of dBA | Standard deviation of sones |
|---|---|---|---|
| 55-hp tractor without cab (second gear) | 8 | 0·8 | 2 |
| 55-hp tractor without cab (fourth gear) | 8 | 0·8 | 6 |
| 55-hp tractor without cab (sixth gear) | 8 | 0·6 | 6 |
| 65-hp tractor with cab (third gear) | 8 | 0·5 | 5 |
| 65-hp tractor with cab (fourth gear) | 8 | 0·7 | 6 |
| Mean | — | 0·7 | 5 |

## Appendix 16.2

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**Paper by A. R. Reece**—*from page* 24

in this country by a major manufacturer it resulted in his share of the tractor market falling in a most dramatic fashion. This was caused by the manufacturer's inability to make the changes involved in a completely smooth and successful manner. This experience has caused most manufacturers to adopt a policy of slow, steady development of both tractor design and manufacturing facilities.

There are therefore powerful conservative forces at work discouraging the attempt to radically advance tractor design. However, if the possibility exists, then this provides a great opportunity for the country or company capable of making this advance. It seems that there may be the possibility of as radical a step forward as that made by Harry Ferguson with his introduction of the TE20 tractor and its implements in the 1940s. The initiative of Harry Ferguson undoubtedly laid the basis for the present leading position of the British tractor industry. The next jump forward could do a very similar thing for the country and company capable of making it.

### Appendix 13.1

**References**

1. REECE, A. R. 'Two- or four-wheel drive', *Fm Machine Des. Engg* 1968 (February) **2** (2).
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# 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 1970–71.

## THE DUNLOP SCHOLARSHIP

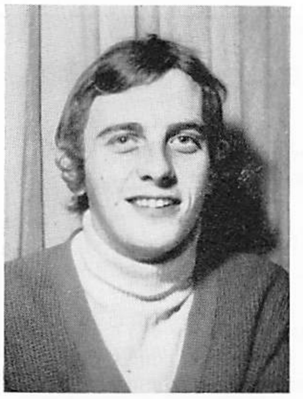
Mr. D. Jones

A Dunlop Scholarship was awarded to 26-year-old **David JONES,** a member of the machinery development team of F. W. McConnel Limited of Ludlow, Shropshire.

Mr. Jones, a native of Ruthin, North Wales, and an honours graduate in mechanical engineering at the University of Strathclyde, started out as an apprentice with Allis Chalmers in Mold, Flintshire. He obtained an HNC in mechanical engineering and subsequently studied for two years at Strathclyde. The Dunlop Scholarship helps Mr Jones to study farm machine design full time for a year for a Master's degree in agricultural engineering at the National College of Agricultural Engineering, Silsoe.

Mr Jones' hobbies include shooting and motor racing, although he admits, perhaps a little ruefully, that the latter is as yet only in a spectator capacity.

## SHELL MEX AND BP BURSARIES



Mr. M. Barrett

Mr. M. Freeman

One of the three students to receive a Bursary was **Michael BARRETT** aged 22, who hails from Skipton, Yorkshire. He went to school there and afterwards joined a nearby Massey-Ferguson main dealer. He attained credits in the City & Guilds 260 and 261 examinations and this helped him get a place on the course at Essex Institute of Agriculture where he is now studying for the ND Agr E.

Mr Barrett, married and with a 2-year-old daughter, likes fishing, shooting, walking and motor cars. His car is of the venerable age where, by his own account, more time is spent repairing it than driving it.

**Michael FREEMAN,** another Bursary winner, also lists among his hobbies "the inevitable student battle to keep my car on the road". It sounds more like a disease than a hobby. However, he also likes sailing, canoeing, swimming, cross-country running and drag racing, so perhaps that all makes up for it.

At 22, Mr Freeman is studying the ND Agr E course at Essex Institute of Agriculture, having already secured an NCA at credit level from Berkshire College of Agriculture, followed by City & Guilds 260 and 261 certificates at Rycotewood College and receiving two "Student of the Year" awards. He then gained some practical experience as an engineering fitter before starting the course at Essex.

Mr. J. Lyne

The third Bursary winner was **James LYNE,** 27, who comes from a farming background. He was apprenticed to John Wilder (Engineering) Ltd and obtained the City & Guilds 260 and 261 certificates from courses at Rycotewood College. He also took teacher training at Wolverhampton and has lectured on agricultural machinery subjects at Notts College of Agriculture. Now he is studying for the ND Agr E at West of Scotland Agricultural College.

Mr Lyne likes photography, motor rally navigation, drama and "many indoor and outdoor sports" details of which are not supplied and we did not like to ask. He has also kept quiet about the state of his car. □

### The Engineer and That Bill

**Sir,**

**I have for some time had considerable anxiety about the position of the professional engineer when the Industrial Relations Bill comes into force.**

**I would support the moves made by CEI on this subject (see "Newsdesk" on page 6) but I do not think these go far enough.**

**The crux of the matter stems from a question of responsibility in the community. The closest equivalents of the professional engineer are probably doctors and lawyers and they are represented by their respective professional bodies in *all* matters including pay, conditions of service, technical and academic spheres.**

**There is never any question of a doctor having to belong to some other body for bargaining or employment reasons and I think it is basically wrong to create a body such as UKAPE largely for the purpose of representing the engineer in matters otherwise dealt with by a trades union.**

**I realise that it is difficult to draw strict comparisons between the professions as their methods of daily co-operation are different but if the engineer is to be recognised as a truly professional man he should maintain this station solely by virtue of membership of his institution.**

**Certainly the Industrial Relations Bill should not require more from the professional engineer than membership of one of the CEI institutions or their future affiliates. If this means the formation of a negotiating committee for each institution or for CEI then this should be accepted.**

**It is frequently forgotten that it is the engineer who has made the biggest contribution to the prosperity of any modern society, since he is creative and it is a tragic reflection of the present state of affairs that professional integrity and success in the rat race of life are rarely compatible.**

T. SHERWEN
(Fellow)

*Minchinhampton,*
*Glos.*

### The Institution Overseas

Sir,

An analysis of our membership indicates that approximately 20% are currently listed as being resident overseas, quite apart from a number of others resident in this country, who have close connections or interests there. This is a very high proportion for any professional institution and is indicative of the part played by Britain in fostering agricultural engineering and farm mechanisation development in overseas territories.

I feel, therefore, that it is very important for the Institution to retain the interest of these members and to try and compensate, in some way, for their inability to participate actively in U.K. based functions. Their viewpoints should be adequately represented within the Institution and their particular needs catered for as far as possible. Many are working in isolated areas and will value regular contact with a professional body which can keep them informed of developments in more advanced countries relevant to their own situation. It is recognised that both distance and diversification of interest are strong deterrents to maintaining such connections but as one who has lived and worked both in this country and overseas I suggest there are a number of modest steps which might be taken to encourage more active participation by this body of membership.

I would therefore suggest that the Institution consider one or more of the following proposals:

(i) that a Newsletter be instituted, possibly as an insert to the Journal, which would be devoted to an exchange of information on the activities of overseas members and institutions.

(ii) that special articles be featured in the Journal, wherever possible, dealing with agricultural engineering activities relevant to overseas agriculture.

(iii) that prominence be given to reports on conferences and seminars biased towards the overseas field, whether they take place in this country or overseas.

(iv) that news topics in the Journal should cover the activities of the many Institutions, Universities, Government and private organisations, concerned with agricultural engineering overseas.

In putting forward these proposals I fully realise that the term 'overseas' covers a large number of countries and a wide range of working conditions, but the majority of members appear to be working in the developing countries and the Institution should therefore be in a unique position to act as a forum for those working in the tropics or sub tropics.

B. P. POTHECARY
(Fellow)

*Colchester,*
*Essex*

# admissions and transfers

At a meeting of the Council of the Institution on 28 January 1971 the following candidates were admitted to the Institution or transferred from one grade to another, as stated below.

## ADMISSIONS

### Fellow

Sakai, J. .. .. .. .. .. *Japan*

### Member

Ayub, M. .. .. .. .. .. *Bahrain*
Grafiadellis, M. .. .. .. .. *Greece*
U Tin Hlaing .. .. .. .. *Burma*

### General Associate

Atkinson, K. G. .. .. .. .. *Notts*
Campbell, D. S. .. .. .. .. *Warwicks*
Clark, R. .. .. .. .. .. *Lancs*
Fuhr, P. L. .. .. .. .. *Warwicks*
Mahmood, R. A. K. .. .. .. *Pakistan*
Smith, B. C. R. .. .. .. .. *Devon*
Stephens, M. A. .. .. .. *Cornwall*

### Technician Associate

Awan, M. A. .. .. .. .. *Pakistan*
Gupta, A. K. .. .. .. .. *India*
Howarth, R. .. .. .. .. *Nigeria*
Kurabatchew, W. A. .. .. .. *Ethiopia*
Oppong, F. J. .. .. .. .. *Ghana*
Riddell, J. .. .. .. .. *Northumberland*
Stamp, R. J. .. .. .. .. *Devon*
Todd, J. A. W. .. .. .. .. *Warwicks*
Wardle, A. P. S. .. .. .. *Bucks*
Weeks, V. D. .. .. .. .. *Yorks*

### Graduate

Bailey, K. .. .. .. .. *Notts*
Dean, R. J. .. .. .. .. *Sussex*
Hamilton, R. E. .. .. .. .. *Warwicks*
Howat, D. .. .. .. .. *Stirling*
Ilamurugan, C. P. .. .. .. *London*
Johnson, R. A. .. .. .. .. *Dorset*
King, G. W. .. .. .. .. *Bristol*
Leggat, R. .. .. .. .. *Glasgow*
McCracken, W. R. .. .. .. *N Ireland*
Miller, J. A. C. .. .. .. .. *Dumfries*
Mitchell, C. D. .. .. .. .. *Yorks*
Mountstevens, M. J. W. .. .. *Somerset*
Nelson, R. L. .. .. .. .. *Berks*
Olatunde, K. A. .. .. .. .. *Nigeria*
Orr, C. R. B. .. .. .. .. *Leics*
Sea Piak-Guan, .. .. .. *Beds*
Sims, K. J. .. .. .. .. *Ches*
Sims, R. E. H. .. .. .. .. *Surrey*
Swinstead, P. H. .. .. .. *Lincs*
Wall, B. P. .. .. .. .. *Middlesex*
Williamson, D. A. .. .. .. *Berks*

### Student

Amupide, S. A. .. .. .. .. *Nigeria*
Barrett, M. .. .. .. .. *Yorks*
Bin Sukra, A. .. .. .. .. *Beds*
Boutflour, D. R. .. .. .. *Essex*
Bradshaw, R. W. .. .. .. *Cumberland*
Brown, D. C. .. .. .. .. *Surrey*
Butcher, P. A. .. .. .. .. *Beds*
Chamen, W. C. T. .. .. .. *Beds*
Culy, D. S. .. .. .. .. *Beds*
Defeu, D. P. .. .. .. .. *Essex*
Enujiugha, R. A. .. .. .. *Nigeria*
Everest, J. .. .. .. .. *Essex*
Freeman, M. D. A. .. .. .. *Berks*
Gollop, W. .. .. .. .. *Essex*
de Heer, J. P. .. .. .. .. *Ghana*
Hiremath, R. V. .. .. .. .. *Beds*
Hutton, J. S. .. .. .. .. *Ayr*
King, P. J. .. .. .. .. *Kent*
Kugaprasad, S. .. .. .. .. *Ayr*
Lyne, J. W. .. .. .. .. *Berks*
McAleese, J. P. .. .. .. *N Ireland*
Marsh, K. C. .. .. .. .. *Warwicks*
Martin, M. J. .. .. .. .. *Lancs*
Maunsell, C. H. .. .. .. *Surrey*
Maynard, M. .. .. .. .. *Yorks*
Mitchell, N. B. .. .. .. .. *Yorks*
Oldacre, N. .. .. .. .. *Herts*
Omoaka, S. .. .. .. .. *Ayr*
Rooke, L. W. .. .. .. .. *Essex*
Russell, D. H. .. .. .. .. *Glos*
Ruston, I. F. .. .. .. .. *Essex*
Rutherford, I. .. .. .. .. *Lincs*
Scott, B. R. .. .. .. .. *Suffolk*
Shah, H. M. .. .. .. .. *London*
Shailes, Miss S. C. .. .. .. *Warwicks*
Sheldon, M. C. .. .. .. .. *Staffs*
de Soysa, V. S. .. .. .. *Beds*
Tailby, G. A. .. .. .. .. *Leics*
Thrmendiran, S. .. .. .. *London*
Thompson, B. J. .. .. .. *Liverpool*
Threlkeld, E. .. .. .. .. *Derbys*
Watts, M. S. .. .. .. .. *Hants*
Walker, L. A. .. .. .. .. *Lancs*
Westgate, G. R. .. .. .. *Surrey*

## TRANSFERS

### Fellow

Ghosh, B. N. .. .. .. .. *Egypt*

### Member

Chick, D. C. .. .. .. .. *Somerset*
Hall, A. E. .. .. .. .. *USA*
von Kaufmann, H. F. .. .. .. *Kenya*
Kellaway, D. H. .. .. .. *Warwicks*
O'Dowd, E. T. .. .. .. .. *Kent*
Opoku, D. K. .. .. .. .. *Ghana*
Ormiston, L. W.. .. .. .. *Yorks*
Thoniappa, T. .. .. .. .. *Ceylon*
Young, P.J. .. .. .. .. *Bucks*

### Technician Associate

Saunders, P. .. .. .. .. *Kent*

### Graduate

Barnes, R. J. .. .. .. .. *Suffolk*
Cheema, M. I. .. .. .. .. *Warwicks*
Edghill, G. .. .. .. .. *Sierra Leone*
Fuller, R. S. .. .. .. .. *Surrey*
Jackson, R. G. B. .. .. .. *Hants*
Photiades, I. T. .. .. .. .. *Cyprus*
Purchas, M. D. .. .. .. .. *Somerset*
Soobrian, L. H. P. .. .. .. *Guyana*
Tulloch, A. J. H. .. .. .. *Suffolk*
Walker, J. G. .. .. .. .. *Lancs*

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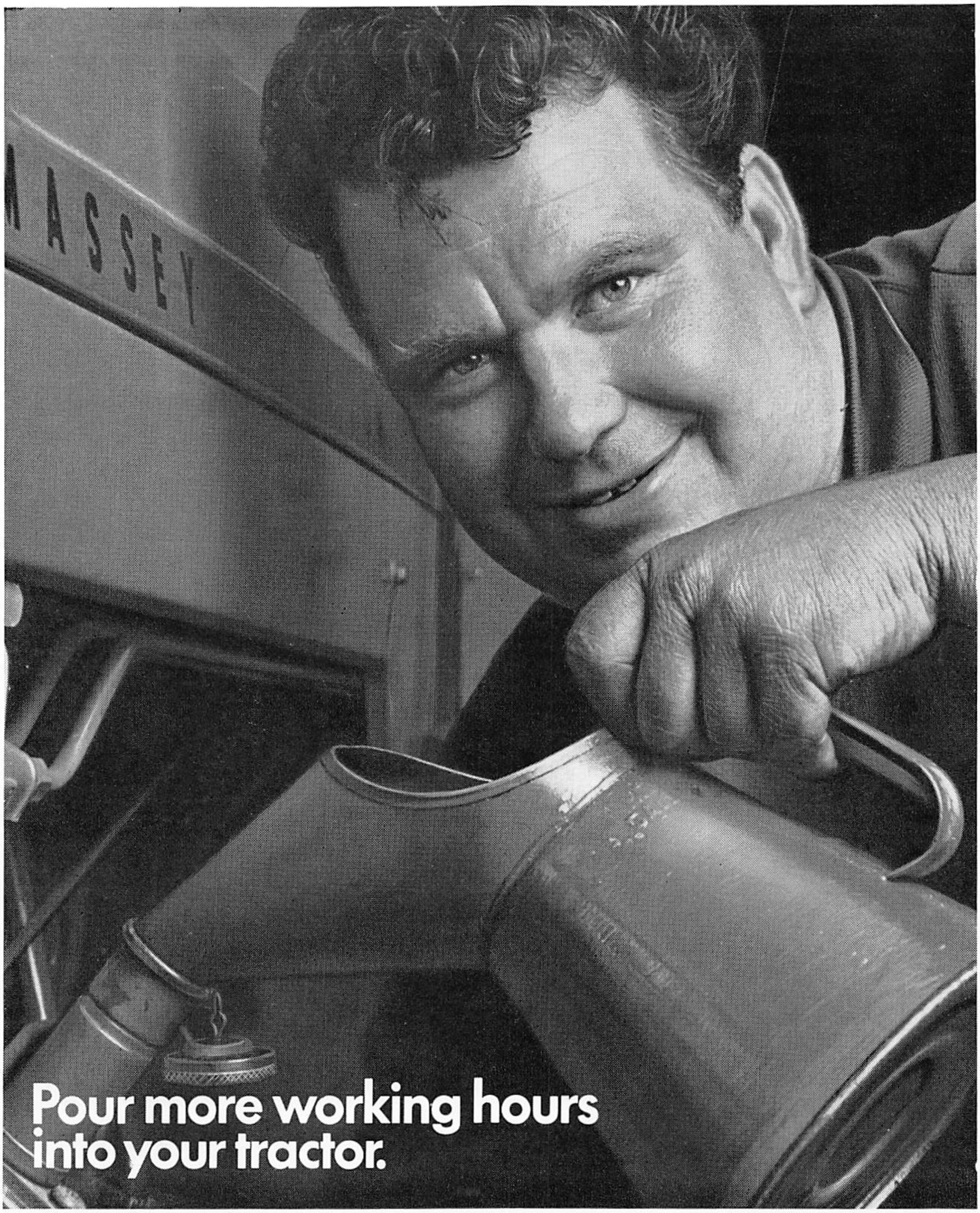


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