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Firing of boilers and furnaces with non-fossil fuels

The Institution of Agricultural Engineers

Journal and Proceedings

Front cover:
Typical example of single and triple pass boilers designed specifically for burning non-fossil fuels (Scanfield photograph).

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The Douglas Bomford Fifth Memorial Lecture

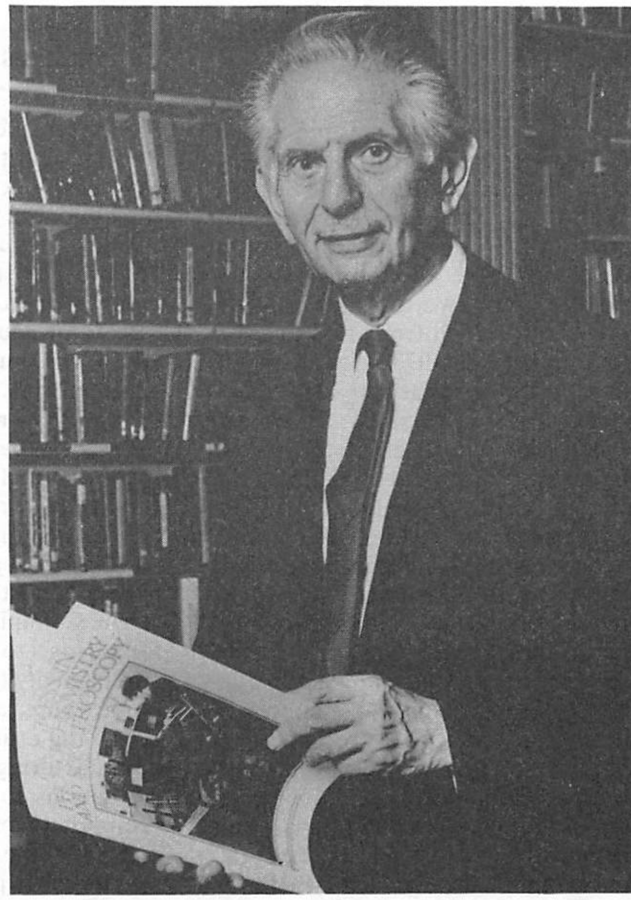
The Agricultural Engineer after the Finniston Report

Sir Monty Finniston

Introduction

THE essential history of modern societies, unlike that of ancient empires, will not be about kings, wars and national boundaries but of industrial growth through technological developments since social and political policies and decisions in these times are principally concerned with advancing the standards of living of the masses. The economies of today's societies provide not just the primary needs of food, clothing and shelter, but also the multiplicity of products and other material features which support urban and rural living and the infrastructure — the machines of the service industries such as transport, communications (including TV and radio), energy (including the secondary fuel electricity), education, health (including the pharmaceutical products) etc. The production of these manufactures requires the practice of knowledge-based disciplines — design, research and development, processing, operational skills (including those in the open air factories of agriculture), the professionalism of supporting administrative/management (including financial control), marketing, personnel, maintenance and product servicing.

In all these activities pertinent to industrial manufacture through to the consumer, it is the professional engineer at various levels of qualified competence who plays a major role. In our society, the accountant, lawyer, doctor, entertainer or politician, however respected and important in his own view, would not be considered, much less claim to be, competent to engage in any of the ubiquitous industrial activities which are the province of the engineer. Yet the status of the engineer however measured is low whether this assessment is by national opinion poll of his importance as judged by the society he serves; or by the influence and authority, social or political, which he holds or exercises; or by his wage earning capacity which ranks below many of those professions already mentioned, and fares badly by comparison with the new peripheral service industries — banking, public relations or stockbroking. Why, it may be asked, if the engineer is as important to society as this introduction suggests, does Britain adopt this attitude to him? In July 1977, the Government of the day asked itself this question and sought an answer by setting up a Committee of Inquiry into the Engineering Profession with the terms of reference "to review, for manufacturing industry and in the light of national economic needs, the requirements of British industry for professional and technician engineers, etc, etc". Notice the constrained terms of reference to "manufacturing industry", but the less constrained context in which this had to be reviewed, namely "*national* economic needs".



How the Committee of Inquiry went about its remit

I had no privileged access to the debates in the Department of Industry (as it was at the time), much less to the Cabinet decision which led to the formation of this Committee which I chaired, but the evidence of the decline in the country's manufacturing base justified the need for an enquiry. Whatever parochial view engineers may have taken of their profession and role in society and however they may have wished to safeguard the status quo of their institutions, these considerations took lesser precedence against the greater national economic need. The most superficial view showed the considerable and necessary continuing contribution of manufacturing industry to the economy as a whole, it showed the

The Memorial Lecture was presented by Sir Monty Finniston on 14 November 1985 at the Institution of Civil Engineers, Great George Street, Westminster, London SW1.

considerable employment provided by manufacturing industries (though this was rapidly reducing because of engineering developments particularly in automation), it showed the high export contribution of manufacturing industry and its major value to the balance of payments, and it obviously contributed directly to the progress in material standards provided by the working talents of the population. All these were good reasons for sustaining and improving our manufacturing base, but what made the situation more telling and critical was that the review had to be taken against a continuing decline in the fortunes of manufacturing industry certainly since the end of the Second World War through the increasing competition of other nations developed and developing. As an example, the world trade in UK manufactures fell from 15% in 1963 to about 9% in 1973, around which level it was sustained in 1984 (8%), market shares declined in almost every UK industrial sector — in British made cars, ships, in steelmaking, in chemicals, in electrical and non-electrical machinery and so on. Some UK industries in which we had world reputation actually disappeared — motor-cycles and cutlery. In 1984, for the first time in the whole industrial history of this country, the import of finished manufactured goods (£74.6 billion) exceeded the export of comparable products (£70.4 billion), and although service industries, our invisibles (not all tradeable, incidentally), do go somewhere to compensate for this decline, every 1% loss in manufactured exports required a 2% gain in the service industries — an unlikely gain when one considers the relative decline in invisible earnings compared with the growing service industries of Japan, Europe and US.

For two and a half years, the Committee of Inquiry debated the various issues, garnering information and putting in hand various studies to gain quantitative facts rather than qualitative anecdotal opinions. Meetings were held up and down the country to which engineers professional and technician were invited to make their views known and provide information on which recommendations for future action might be based; relevant professional institutions were invited to comment, education establishments at all levels — universities, polytechnics, schools — were visited and interviews and opinions gained of academics, engineers in all manner of industries and activities, and employers to Chairman level in companies at home and abroad (Germany, Japan, France, the United States, etc). Out of all this, the conclusions and recommendations of the Committee of Inquiry emerged in their Report "Engineering our Future" Cmnd 7794 issued by HMSO in January 1980.

The findings of the Committee of Inquiry

Based on the conclusions of the Report, about 80 recommendations were made covering the supply of engineers and their employment; the changes required in schools to prepare girls and boys to consider industry in its technical context as a career; the education and training of engineers and their continuing development, their registration and licensing; the role of the institutions; the relation between the professional engineer and trade unions; the actions required of employers and the formation of an Engineering Authority. Of all these, the two latter were the most important.

The Committee of Inquiry pressed for change to overcome the inertia and passivity (even negativism might be a more appropriate word) of prevailing attitudes in the UK on its manufacturing future and to press for actions to advance the national economy through acceptance of the concept of the engineering dimension as a guiding principle to employers since it is the employers who create wealth through growth of industry. (Growth in this context does not just mean enhancing the output of existing firms but also in increasing the number of businesses and their product scope from their present level). It is the employers, the industrial leaders, who decide in what they will invest, how much they will invest, where they will invest, what they will produce, their markets, to whom and where they will sell, whom they will hire or fire and what they will pay. In its conclusions and recommendations, the Report of the Committee of Inquiry pointed one finger of responsibility particularly and directly at employers in the summary of recommendations. "To emphasise the importance we attach to initiatives lying with employing organisations, we draw attention by repeating 18 recommendations which apply to industrial companies". (There were a number of other recommendations which would also entail action from employers though the principal initiative rested with other bodies, notably the Engineering Council.)

The important feature in our recommendations to employers was the concept of the engineering dimension, a concept based on the premise that "the capability of any organisational system engaged in manufacture depended upon translating engineering expertise into the production or marketing of competitive products through efficient production processes". This capability involved not just engineering but association of engineering with non-engineering factors.

That sense of interaction in determining manufacturing performance and the emphasis on the importance of considering the whole system and not just aspects of it, was encompassed in the term 'engineering dimension'. The concept of the engineering dimension determined the impact of engineers on a wide (if not total) compass of industrial/commercial activity; for example

- it related to company responses to world markets particularly in assessing and/or anticipating market needs and opportunities;
- it related to assessing the company's engineering developing products and systems to meet market requirements;
- it involved developing, operating and improving processes from manufacturing such products profitably and making optimum use of materials energy capital and human resources;
- it had to ensure that engineering support for products was effeciently sustained throughout product life; and
- it required flexibility to adapt to particular market requirements and responding quickly to changes in those requirements or in the technical potential needed to meet them.

In all these aspects, the importance of the engineer is obvious but how much involvement is there of engineers in the totality of business? In the main, the engineering dimension has failed to be recognised by people running businesses which involve engineering. There are exceptions but these are limited and do not reflect on a national scale the engineering input necessary to the successful manufacturing industry. This stricture applies also to industrial services which use engineering products of complexity for example computers. Against the professionalism of competitive companies at home or in foreign countries, amateurism is neither sufficient nor pertinent to British industry today.

Investing in change

Has the economy realised the importance of engineering and hence of engineers to its future improvement? The answer must be that some politicians, economists and investors most recently supported by a House of Lords Select Committee on Overseas Trade confirming the concerns of the Committee of Inquiry and re-iterating the findings of "Engineering our Future", do acknowledge that the decline in manufacturing industries in this country has gone too far and that the recovery of the economy depends principally if not wholly upon reversing this situation. But as ever, there is a large time gap in affairs between becoming aware of a problem, generating a solution and implementing it in meaningful and significant fashion. The fact is that investment in new businesses is not at a level which is arresting the decline, much less improving the visible sector of the economy or creating the employment to reduce the present abysmal figures of the unemployed. There are many reasons for this, but the major reason and one which the Report emphasises is that, in the UK, the investing public is not conditioned to accept the risks entailed in the production of new products and new markets against international competition on our own home territory as well as abroad; investors prefer the certainties of Building Societies, Pension funds, Gilt Edged Securities and the privatisation of nationalised near monopolies even although these investments of themselves do not generate the extra wealth much less the extra employment in the essential manufacture or service industries.

What is required is a more relaxed (not lax) financial attitude by venture capitalists to investment in the new technologies or in modernisation of the old. On their own say so, finance houses claim that there is a sufficiency of money available but that what is lacking are ideas, concepts or management in which to invest. There is much evidence to rebut this contention. The Unlisted Securities Market and Over-the-Counter ventures investments have grown rapidly in recent years, and from my experience the awards schemes whether the Prince of Wales Award Scheme for Production and Innovation, the Industrial Achievement Award (which incidentally is sponsored by accountants), the various awards schemes run by institutions concerned with industry, eg Association of British Chambers of Commerce (ABCC) and by publishing firms, eg the Eureka Awards, the Patents Office, the trade journals, all throw up attractive commercial possibilities based on engineering ideas and concepts. Grants like SEFIS (Small Engineering Firms Investment Scheme) which offered relatively small sums of money to small engineering firms were eagerly taken up (which pre-supposes that there is a body of people eager to advance manufacturing industry). There is too the Business Expansion Scheme which allows individuals to support industrial investment and avoid tax in the process. (This may not exactly appeal morally but it can work to the benefit of industry.)

As to management, it may well be that there is insufficient expertise amongst British managers — (actually management is a scapegoat for others' errors in many cases) — but it is up to the professional investing public to supply such disciplinary advice as may be lacking and help to fill the gap of inexpertise. The Government in a generalised fashion attempts to do this through various of its advisory schemes, but what is wanted is specific advice and help particularly in accountancy and control of finance whether in a decision making process or in marketing and selling. Here the larger established companies can help as I have seen done by such enlightened companies as Shell, ICI, etc and organisations like Business in the Community. The future of British industry requires political decision; not party political decision but policy decision. Britain has suffered from the lack of an industrial policy such as the French, Germans, Japanese and the Americans have had over the the past decades as part of their national direction. It is time that Britain followed suit relying upon that inherited engineering talent which gave such positive direction to the UK in the 19th century and which has sadly declined in the latter half of this century. That talent is still there — all it requires is encouragement of its professionally qualified engineers and there can be no better encouragement than the allocation of resources through investment in present and future technologies in manufacturing industries.

A change of attitude towards support of industrial regeneration and growth in this country however, implies an educational process. Such a process is not quickly or easily effected. Since education implies communication, what is needed is a concerted communication between all engineering organisations, institutions, companies and practitioners of engineering wherever and in whatever form to press hard not just on companies and their directors or senior management, but on the City and the investing public including the Government.

The Engineering Council

The Committee reached the conclusion that to secure radical change on a national level, an authoritative permanent champion capable of marshalling the many diverse interests concerned and of overcoming the apathy, inertia and resistance to change which exists amongst them, was needed. It foresaw the need for a national focus to which engineers and society in seeking the help of engineering skills, could turn. It therefore recommended the establishment of a new Engineering Authority to create an environment in which the engineering dimension could be given its due weight through efforts to stimulate a vigorous and dynamic national manufacturing capability and to ensure the availability of an adequate supply of properly qualified engineers to progress these efforts.

The Committee detailed the terms of reference and remit of this Authority. Its main terms were that it should be broadly constituted and representative of those who were concerned with manufacturing industry whether employers, employee or investor; it had to have independence and authority to command national and international respect; and it should be able to overrule vested interests where these contradicted the national interest. This required that the Authority should have a statutory basis and access to funding of its own. Instead of the statutory Authority which would have had a public forum in Parliament to state its views and policies and which could have pressed Governments to heed its advice on the economy of the industrial sector, allocate resources, apply pressures and set example through its purchasing power, a charter body — the Engineering Council — was set up. This charter body had inadequate and restricted resources in finance and limited authority since it depended wholly upon its persuasive powers. To create an environment which rehabilitated engineering and engineers into the body economic, the Council had to work within a fragmented complex of institutions, of qualifying bodies, of learned societies and tertiary educational complexities in a background of increasing financial constraints and without the unified commanding voice which would influence employers to radical action to the benefit of their companies or the industries which they served.

The reasons for not having the Authority are absurd to put it mildly. It was said, for example, the Government did not want a 'quango' although it still persists with several thousand and the Council is one in disguise. It was argued that the Authority would be run by individuals subservient to Government wishes, but the Report identified the character of the Chairman and members of the Authority, and it has been known for public bodies to have Chairmen and Council of independent mind and courage (particularly engineers). Furthermore Government interference was safeguarded against in the Report by accepting that the initial members of the Engineering Council had to be selected by the Government (which actually happened with, incidentally, consultation with the engineering fraternity), but election to the Authority by its membership would eventuate in due course when the register of members had been revised, which is what is actually happening.

The view that the Council being an appointed body was a form of disguised dictatorship carrying out Government policies (which are never formulated) is one of those myths of British institutional conduct which people conjure in their restricted imagination. The Council has met this "criticism" by creating the Engineering Assembly, a democratically elected body. Nineteen regional constituencies each elected four chartered engineers and two technician engineers/ engineer technicians to the Assembly. The balloting of the membership which cost some £100,000 (democracy is a costly business) was based on the electoral register of the Board of Engineers Registration. Regions are to have public relations unpaid officers who will collect information on the public reception of the Council's activities, pass on suggestions which will advance engineering and engineers' interests in the regions as well as garner news from the academic institutions and industry centred with their regional area.

The Assembly met for the first time in September 1985. The Prime Minister giving the keynote speech committed her Government to the engineering dimension. "The success of engineering is the key to our future prosperity", and "If business is to survive and flourish, engineers have to design and create tomorrow's products today. It is engineers who will keep our industries a step ahead of the rest", and again, "It is for the Government to create the right background and for the engineers to make our future prosperous." The speech reads like an extract from the Finniston Report but on 6 November 1985 the Queen's speech was silent on the subject. The Engineering Council itself was proposed in November 1981, became operational in 1982 and had final Privy Council approval in 1983. How then has the Council fared in its short existence? The general answer must be "not badly" but only as far as setting its own house in order where this relates however only indirectly to the economy proper, eg in rationalisation of the institutions in education in standards, etc. I elaborate below on some of these.

Progress by the Council

(a) The Institutions and Membership
One would have thought the Finniston Report was professing lese majeste when it called attention to the weaknesses of the governing Council of Engineering Institutions (CEI) but the Engineering Council has done much to put the internal organisation of engineers in closer order than obtained with the federated institutional structure of the CEI. A relatively immediate and pleasantly surprising success of the Council was the transfer of the titles of Chartered Engineer, Technician Engineer, and Engineering Technician from the CEI to the Engineering Council and the setting up of the Board for Engineers' Registration. The register has passed to the Council and it is now possible to identify the core (or should it be corps) of the profession, and have a base from which to expand the membership.

In this connection, the Council has recognised that engineering is a very diffuse discipline become more so as one borrows from physics, chemistry and biology. The Council has set down rules by which physicists with an engineering bias in their discipline can achieve engineering registration through part accreditation, and special cases, eg the mature student catered for through various bridging techniques. These moves which relate to "relevant technology" can only strengthen the professional expertise which engineering demands today — and will be even more necessary tomorrow. Bio-technologists may for example be the vanguard of tomorrow's agricultural engineers. The attempts to enlarge the cohort of engineers through the energetic efforts of schools-industry liaison groups, support of SATRO (Science and Technology Regional Organisation), and the WISE 84 campaign (Women in Science and Engineering) are all useful prods as is the positive Council support and administration of the Young Engineer Award, the National Engineering Scholarships, Opening Windows on Engineering etc.

For such a relatively small cohort of registered engineers (some 300,000 at present) there are still too many independent 'specialist' institutions. The Council's effort to control this fragmented institutional structure of engineers serving their varied interests is to classify 51 of these institutions into five groups. (The Institution of Agricultural Engineers is in Group 2 with 11 other bodies.) This has much to commend it, although further concentration particularly within the members of groups is still desirable. One or two institutions are trying to merge, but resistance to consolidation is still the norm. If I may bowdlerise Winston Churchill's comment on Clement Attlee "Institutions combine a limited outlook with strong qualities of resistance".

(b) Education

In accord with the terms of the charter "to advance education in and to promote the science and practice of engineering (including relevant technology)" the Council has worked hard to set standards of education, training and experience as a basis for qualification in all three categories of engineers. The principles on which these standards were based and the intended practices to implement them were first tried out for size in October 1983 in a consultative document (Standard and Routes to Registration (1985 onwards)). Response came from about 400 sources including 100 from industry which is very good compared with the submission record to the Committee of Inquiry. The consultative document has also been subject to independent analysis to avoid suspect bias in the Council. The final document issued in September 1984 closely followed Chapter IV of the Report.

On the educational front there has been much effort by the academic institutions to introduce the more obvious beneficial elements of education into the engineering curriculum. In universities and polytechnics AE1 and AE2 are now established, and enhanced courses are being developed. The academic institutions, however, are finding difficulty in playing their part to the full by the inconsistent financial policies of Government through the drying up of resources, resources which are not compensated for by industrial funding. The recent injection of £43M (over three years) by the Department of Education and Science to swing the balance in tertiary education to the sciences/engineering from the arts, is indicative of a change of none too generous a heart! There is also effort being made to stimulate continuing education and training, but this will be a long haul.

The educational system in this country* and particularly in vocational knowledge and skills is now being divided between the Department of Education and Science and the Manpower Services Commission, the latter having some £1B to spend. None of this latter however is being directed towards support of the technician classes. The Council could certainly use some of the MSC money to the greater benefit of the two technician classes of engineers. On technicians in particular the Council has no defined policy although one is expected to be announced in the near future. The Finniston Report drew attention to the need for a Committee of Inquiry into the technician problem as a necessary input into the conduct of the profession as a whole. In my Presidential address to the IMGTE (Institute of Mechanical and General Technician Engineers) this year, I calculated that 150,000 more were necessary to match the professional output of chartered engineers allowing only two technicians (of either grade) to every professional.

The Engineering Council Examinations Part 1 and 2 have been a major success. In 1984/85 roughly 5000 entered for these examinations, about half in Part 1 and the other half in Part 2, of which 1000 are home based and 4000 from overseas. For 1985/86 the examination entries seem to be continuing on the increase. (Is this a further example of our engineering being more honoured abroad than at home?) Some £1.8M of income is expected to result from examinations and registration fees.

The Report "Engineering our Future" was clear that engineering would not prosper in this country unless employers paid greater attention to engineering in their business and to engineers who knew something about engineering. The Council have constituted an industrial forum of industrial affiliates who contribute depending upon their size to the Council's coffers. These affiliates who number 115 at present (large, medium and small) have been garnered from the main engineering concerns within the country. The first meeting took place on 4 November 1985 and the ground gone over once more — how is one to advance engineering as part of the culture, a way of life of the country, and maintain professional standards. One can applaud a beginning however.

The Council's publications on technical and commercial aspects of manufacturing and process companies are basic documents which draw attention to what is needed to become a success or at least not fail. The relationship between the Fellowship of Engineering and Council is good and the Fellowship itself is making strides in publicising the role of engineering and engineers in the economy of the country but with more success with the converted than to potential converts.

(c) Status

A sore point amongst engineers has been their status classification in terms of salary, perks, and promotion prospects, and this is where employers could do something to advance the interests of the profession. In this year's survey of salaries by the Council, the average salary of the professional is placed at £15,000 odd. In a Hay-MSL survey for the same period, accountants rank over £20,000. It is interesting to note how accountants have raised their status publicly in the exercise of their profession. In my lifetime they have graduated from being clerks (a low form of industrial life) to chartered accountants (the presently highest form in the industrial kingdom). Yet the Institute of Chartered Accountants has only some 70–80,000 members where engineers number at least 300,000–350,000. One asks what did accountants do that engineers could not copy to their betterment? Since there is no professional body or trade union for professional engineers to stake their claim to place them in a higher level of salary ranges than at present obtains, what could be expected as a start is for established engineering firms with high national and international reputations to give equal (if not favoured) opportunity to engineers to attain positions of influence. Engineers who understand the needs of their professions and the engineering dimension in positions at Board level, either as Chairmen, Chief Executive, Managing Director, Technical Director, Personnel Director etc, could set example not only within their own firm but to the engineering body politic. The most impressive support for this view is to be found in Japanese industry, or French or German or American. Where this policy does pertain in this country, we see evidence of

**England and Wales.*

consequent economic success. Industrial affiliates should take note.

(d) Publicising engineering

There is a need for a continuing campaign in the media to make known the value of engineering and the engineer. The ignorance of the public of the role of the engineer is monumental. In the National Opinion Poll survey (carried out at the request of the Committee of Inquiry), 65% considered the engineer as a manual worker (boiler suit, sweat rag and oil can) and 19% did not know what an engineer was! The Engineering Council had a recent publicity campaign around the theme of Britain's industrial decline and the steps needed to combat it. This had an impact but the advertising was not sustained. The price of recognition is eternal advertisement. Other professions have this freedom and make use of it. Even the Royal Society (following a report by Dr Bodmer) has made "a strong case for the importance of an understanding of science by administrators, businessmen, politicians and the public in general and no less cogently argues that a prime responsibility rests with the scientific community itself". For science and scientists read engineering and engineers. There is particular need for the educational system from school through university into continuing development to continually apprise the public of the value to them of the products of their system, how they originated and to whom the primary rewards should go.

Although to convince the total population of the value of engineering and engineers to the industrial economy would have considerable advantage in changing attitudes for the future, the urgency of the present state of the economy demands corrective action where such action can be more immediate. This is in the creation of new businesses and in the employment of professional engineers to advance the technology and operations of new and existing manufacturing industries whether this be in the introduction of new processes, automation, design improvement, research and development, etc; in short introducing engineers to meet the opportunities suggested by the engineering dimension. It is to employers, however, particularly, to which the publicity campaign should be directed, not the lay public whose only contribution can be in side-line support. The creation of industrial affiliates of the Council is to be commended.

(e) Summing up

The verdict must be that unlike previous official enquiries covering the engineering profession in various aspects going back to Playfair's report in 1852, action through the Engineering Council and supporting institutions is being taken to advance engineering consciousness in the body politic and hence the role and status of engineers in the UK economy of which manufacturing is still the major element in the creation of wealth. The Engineering Council which was formed as a result of the Committee of Inquiry Report into the Engineering Profession has made creditable progress considering the short time it has been in existence.

The Finniston Report said "to accomplish its remit the Authority (read Council now) must have recourse to added resources and powers of its own". The bad news or not so good news is that from now on the going will be hard, mainly through limited finance since the Government grant ended in mid-1985. The Engineering Council is not an end in itself but a means to an end that end being "to promote industry and commerce in the United Kingdom". The Government has not rendered unto Caesar that which should be rendered, and without resources the Engineering Council is going to be hard put to further significant progress. Whether this will be compensated for by other resource sources to execute Council's remit remains to be seen. This test will determine whether creation of the Council as a chartered body is a cosmetic whitewash for engineers and engineering, or whether notwithstanding its financial constraints Council will emerge as a fighting force and lead in the near future to the acceptance of engineers by industry, commerce and society as an essential element in the conduct of the economy.

(f) Financing the Council

The efforts of the Council to finance itself have been commendable. Revenue for the Council will come from three sources;

- contributions from industrial company affiliates;
- registration from professional engineers;
- projects ranging from publications to carrying out Government schemes.

Target income from industrial affiliates is £500,000 a year. So far 90 companies have come in, promising £328,000 a year. They include many companies like Shell, ICI, Courtaulds and Glaxo, nationalised industries, electrical and electronic firms GEC, STC, IBM, Racal and Ferranti, and many in heavy engineering like GKN, Northern Engineering Industries, Vickers and Rolls-Royce.

Registration and admission fees are expected to rise to £1.4M.

The Council forecasts total income in 1986 at around £2.85M with £499,000 coming from examination fees and some £260,000 from three national awards and competitions. Special project income is set around £290,000.

It may well be that the Engineering Council will, through its continuing efforts, achieve a resurgence of engineering activity as part of the regeneration of British industry. I hope it does, but if this were not to obtain within the next decade, it might well be that the Council will have to be given extra powers probably through greater Government support and modifying the terms of reference more towards a statutory Authority than a chartered body. The Prime Minister in her closing address to the Conservative Conference at Blackpool on 11 October said, "Come with us then towards the next decade. A Britain where there is a resurgence of enterprise with more people self-employed, more businesses and more jobs". If this Government (and any other) is looking to where that enterprise is to be found, they need look no further than our engineering talent; if the Government is looking for more businesses it is in manufacture enterprises that more wealth, more employment and more services will accrue.

The Agricultural Engineer

How does all this relate to the agricultural engineer? There are various features of agricultural engineering which can well be practised by our manufacturing industries in general to their greater advantage. Firstly agricultural industries are efficient by whatever standards one cares to judge by them — output per pound of capital investment or output per man year. It is astonishing how much of our food is produced in this country by roughly 300,000 farmers and assistants, but it is an example of how manufactured product from factories — machinery, chemicals, fertilizers, herbicides and insecticides etc — are responsible for much of this improvement and efficiency over the century. Technology in one field supports technology in others. In all branches of the farming industry is to be seen the use of science and technology to improve the quality of the product which is constantly being sought by new technological practices. Douglas Bomford (and his successors) saw the need for industries' products to support agriculture and he himself provided the means, moving from contracting to manufacture.

Secondly, the agricultural industry is blessed with a focal source of research and development in the National Institute of Agricultural Engineering (notice Engineering not Science although it also practises this latter). The Institute has received the Queen's Award for technological achievement in 1984 and the vast increase in the number of its patents over the years since its inception in 1966 is complementary evidence of its worth to the industry.

The number of successful commercial machines as a result just of the National Institute of Agricultural Engineering run into very nearly 30, all of which have an important effect on the practice of agriculture, and the cost effectiveness of research and development both in an individual farming context as well as a national context is astonishingly large whether this relates to improved spraying techniques, the non-burning of straw, making farm tractors suitable for various kinds of soil as well as helping the developing world. The agricultural engineer is contributing to the balance of payments indirectly through the sale of machines, chemicals or consultancy to meet conditions in countries with different climates, soils and farming requirements from those obtaining in the UK.

Thirdly, would it be mistaken to relate the continuing development of agriculture in this country at any rate to the fact that this industry is the one major industry which has an employers' union — National Farmers Union? Here we have the very centre of the development of an industry being catered for by people with identical interests who can determine the future of the industry by reason of their being employers. Manufacturing industries in their various industrial aspects may have similar groups who set the standards for their particular industry, but these are generally trade associations less concerned with the future of their industry in such matters as education, training, research and development, etc, than in commercial affairs, including legislation, fiscal or otherwise.

Fourthly, the agricultural engineer is a man or woman of many parts who has to know something not just of agriculture in a narrow sense but be aware of chemical material sciences, electronics, biological sciences, and also take into account natural factors, soil irrigation, drainage, harvesting, processing and storage; they have to be aware of energy conservation of waste products; and they are responsible for livestock with its varied disciplinary knowledge and practice. To cater for all this requires all the appurtenances of modern engineering schools and university departments for these various aspects of agriculture.

Agriculture in this country recognises the value of education and training — the formation process of the Report — at all levels of qualification. Witness Silsoe College, Writtle College, Ryecotewood College, etc and the relevant departments in our tertiary system of universities and polytechnics.

And not just the formalities of education but research and development of processes and on manpower, and above all making the industry attractive to engineering and hence engineers to practise.

The agricultural engineer is just as much confronted with new technologies as the engineer concerned with industrial product manufacture. One such is bio-technology. Bio-technology covers techniques using the potentialities of micro-organisms, plant or animal cells or biochemically active fragments deriving therefrom. These techniques are based on basic knowledge gained mainly from biology, biochemistry, microbiology, enzymology and genetics. The fields of application of these new techniques are extremely wide, but there are three main sectors affecting agriculture.

1. Seed production and reduction of intermediate products — therefore costs in fossil energy — by new nitrogen fixation techniques.
2. Agro-feeding, in which new outlets are likely to appear for agricultural raw material in the chemistry or energy industry; but traditional markets, sugar, may be jeopardised and new plants could be developed by genetic modifications which could alter the areas of culture and the traditional industries.
3. Energy: with the different petroleum crises, research into new sources of energy has meant that various countries in the world have become more interested in biomass. The most frequently envisaged combustibles of biological origin are ethanol, and in the longer term, methane and hydrogen.

Professor John Ashworth, Vice-Chancellor, University of Salford, at a recent conference "Future Development in Technology: The Year 2000" in his account of the bio-technology revolution said:

"Just as microelectronics has not only given rise to new chip-making industries but also profoundly influenced the whole of mechanical engineering industry, so biotechnology will profoundly influence the agriculture, forestry, fishing, chemical, pharmaceutical and food industries."

Will the future agricultural engineer become a bio-engineer? Will agriculture become an indoor factory industry? How will the industry adapt to this new pervasive technology in education training, investment etc?

The Finniston Report can be read to apply to agricultural engineering just as much as it can to manufacture, and the association of the Institution with the Engineering Council is a recognition of the acceptance of agriculture as one of the many facets of engineering. Perhaps through the example of the farming community, the standards of qualification, salary and status of the agricultural engineer may in a wider national context be recognised as the classical example of the British engineer of the future.

It may well be that through our membership of the EEC, harmonisation of our treatment of the engineer with his European counterpart may well advance his status in the country. Perhaps the Engineering Council should seek closer cooperation with this wider union, and who better to use their good offices to this effect than the agricultural engineer.

Conclusion

In the preparation of this paper, I have had access to the specialised knowledge of many people in the Institution and am grateful to them for their willingness to contribute their views. I have not attempted to summarise these but with modesty suggest that most are met in some part of the Finniston Report. As an example, the engineering dimension (under another name) and the role of agricultural engineering was debated at the 1985 Annual Conference "Agricultural Engineering Towards the Year 2000" and concerned itself with manufacture in the agricultural scene and the export of that success, the need for investment in innovation engineering, in marketing, etc.

You were doing a Finniston before the Report and I would hope that you would continue to use your influence to advance your industry's interest by support of the Engineering Council. Happily, you are not complacent about your industry or have disregard of its tasks for the future, and the address by the Director General of the Agricultural Engineers' Association at the Institution's Annual Luncheon reflects this. Let me therefore end with a quotation from him.

"Perhaps the most striking feature (of the data gathered) by Ms Angela Whelan for the AEA was the comparatively small number of Chartered and Technician Engineers, of all disciplines, employed in the industry — under 6% of the total workforce. Furthermore, qualified agricultural engineers represented less than one fifth of that 6%; but they were mostly employed in marketing and sales, rather than product design where one might have expected to see their special expertise deployed. I express a personal view when I say that to reverse the trend of import penetration, we must attract more and better engineers into manufacture industry. They must have the right rewards for their labour, particularly when compared with other areas of endeavour in agricultural engineering. And finally, they must have the right background. All our Members emphasised the need for a sound agricultural background for those involved in the design and marketing of their products. Often this last point can only be met by being part of a farming family and gaining in-depth experience working on the home farm."

To which I can only add, "Hear, hear" as would Douglas Bomford who set the example you are trying to emulate, long before the Finniston Report.

A system to monitor tractor drive tyre radial deflection on-the-move

P F Hemingway and M Grigor

Summary

THE desirability of a system to monitor the level of tractor drive tyre radial deflection is outlined, with reference to previous work in this area. The problems evident in constructing such a system are identified. A system is described utilising ultrasonic ranging as the measurement technique and tests on the system when installed on an 18.4 × 34 cross-ply drive tyre are reported. The potential of this system to researchers in the field of off-road traction and to others is suggested. The possibility of linking the system to a centralised tyre inflation system in order to maintain tyre deflection levels at a preset value is discussed.

1 Introduction

THE problem of transmitting high levels of power to the ground using pneumatic tyres, whilst simultaneously minimising soil compaction and structural damage, is one that has become much publicised in recent years.

The benefits to be derived from operator control of tyre pressures via a central tyre inflation system (CTIS) in off-road situations have been well documented for military vehicles by Czako, 1974, and Warner, 1975. The feasibility of incorporating a central tyre inflation system on to agricultural tractors was discussed by Hemingway *et al* (1982) and the desirability of such a system from the agricultural point of view was highlighted by Campbell *et al* (1984).

The relevance of the level of tyre deflection (fig 1) to the off-road performance of military vehicles was investigated by Knight and Green (1962). Techniques for the measurement of tyre geometry in a static situation were described by Painter (1980). Results were obtained illustrating the increase in tyre deflection with load for a 13.6/12-38 tractor drive tyre at four levels of inflation pressure on a hard surface. Abeels (1976) demonstrated that, over a working range of half to full load, both tyre vertical deflection and horizontal bulge at the bottom dead centre position were linearly proportional to vertical loading for a number of different inflation pressures.

This project was undertaken whilst Paul Hemingway was on secondment from the Agricultural Engineering Department, Harper Adams Agricultural College, Newport, Shropshire, to the Agricultural Engineering Department, Lincoln College, Canterbury, New Zealand.

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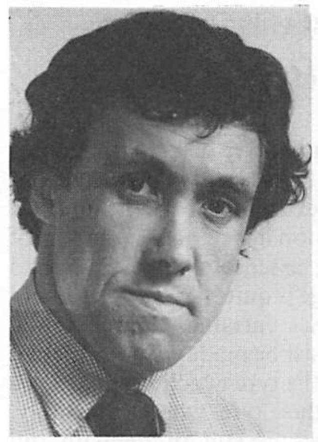
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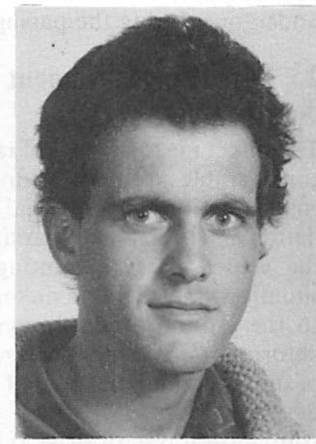
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As a preparatory step to detailed investigation of the tyre/soil interface, Painter (1981) developed a mathematical model of deflection levels in agricultural tyres working on hard surfaces. The validity of the model was checked using physical measurements on a variety of tyres.

Domsch (1959) illustrated that tyre deflection levels changed not only with inflation pressure and loading, but also with the deformability of the soil surface. Tyre deflection levels were noticeably lower when they were run on soft surfaces due to the ability of the surface to deform and increase the contact area until sufficient area was available to carry the imposed load.

It is widely accepted that a high proportion of carcase failures in tractor tyres are caused by excessive sidewall flexure induced at high levels of radial deflection.

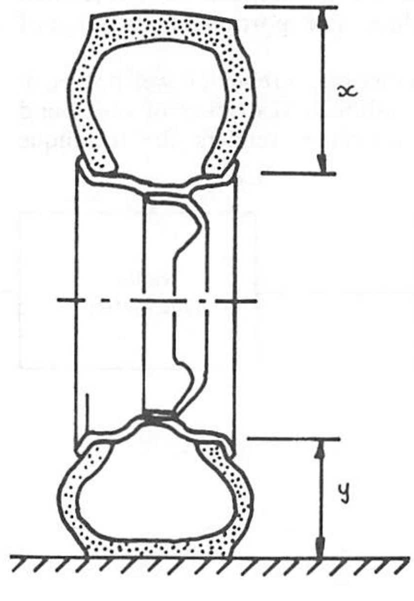


Fig 1 The tyre deflection, d = x – y metres or 100 (x – y)/x(%)

The deflection of a pneumatic tyre is a function of tyre loading, inflation pressure, carcase stiffness and working surface. For the development of high levels of tractive ability, load carrying ability and longevity of tyre life the deflection must fall within certain limits imposed by the tyre manufacturers. This is normally expressed in terms of inflation pressures necessary to carry certain loads in either on-road or off-road conditions. It can be appreciated that a system enabling the monitoring and possible control of tyre deflection levels on-the-move could have significant application in terms of tractive performance, tyre life and the soil structural changes undergone during the passage of the tyre.

2 Direct measurement of radial tyre deformation

The direct measurement of radial tyre deformation poses considerable problems. For tyres used solely in an on-road situation, the potential exists to use the ground as a datum and measure the variation in height of some part of the vehicle wheel mounting assembly. In an off-road situation, considerable sinkage is quite likely to occur and so the ground datum becomes variable. Consequently, deformation measurement must be made between the rim of the wheel and the tread of the tyre which necessitates a device mounted within the tyre/wheel assembly. Agricultural tractor drive tyres are still, in the main, run complete with inner tubes, and so it is likely that any sensing device would have to be contained within the tube.

Tupper (1984) reviewed measurement devices currently applicable to this situation and concluded that the use of ultrasonic ranging was probably most appropriate. This technique involves applying a high frequency electrical pulse to a piezo-electric crystal. The crystal oscillates in sympathy with the applied voltage, causing the surrounding air to vibrate in a similar way to that emanating from a loudspeaker. The ultrasonic pulse propagates through the air at the speed of sound, reflecting from any reasonably smooth surface (fig 2). An attenuated pulse is received by a second piezo-electric crystal, mounted near the first, causing it to oscillate and thereby create a measurable electrical potential. Measurement of the distance to the reflective surface is made by timing the interval between the transmitted pulse and its return. For a constant velocity of sound propagation, the time interval between the transmitted and received pulse is directly proportional to the range of the reflecting surface.

This method of distance measurement is well proven in both air and water, although scattering of the sound waves at air/water interfaces renders the technique impractical in situations where air bubbles are entrained in water. The potential for this type of system to measure tyre deflection in water ballasted tyres is thus low.

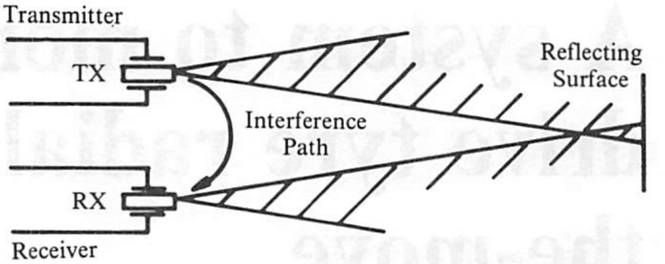


Fig 2 Ultrasonic ranging–signal path

The piezo-electric crystals commonly used for ranging in air have very little mechanical damping to ensure adequate acoustic coupling. They therefore continue to oscillate long after the electric stimulus is removed and this continued oscillating or 'ringing' of the transmitter swamps the return signal to the receiver. This phenomenon normally limits the distance measured in air to a minimum of 0.5 m. The requirement to measure distances in the range 200–400 mm in this application necessitates the development of signal conditioning circuitry to overcome the interference caused by ringing.

3 System design

The system developed consists of three main parts (fig 3). The ranging circuit supplies to, and receives signals from, the piezo-electric transducers which are mounted inside the inner tube (fig 4). The ranging circuit returns to a radio transmitter a voltage in direct proportion to the distance measured. This voltage is used to modulate the frequency of the transmitted signal. The signal is received by the receiver/decoder which reproduces the output of the ranging circuit.

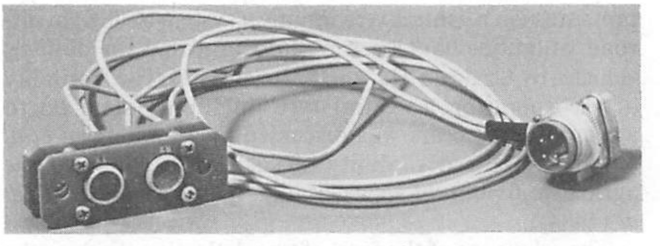


Fig 4 Ultrasonic transducer assembly

The ranging circuit and radio transmitter are housed in a metal box attached to the wheel centre (fig 5). The receiver decoder is housed in a similar box off the tractor.

Ranging circuit and transducers

An oscillator (CLK — fig 6a) produces a square wave

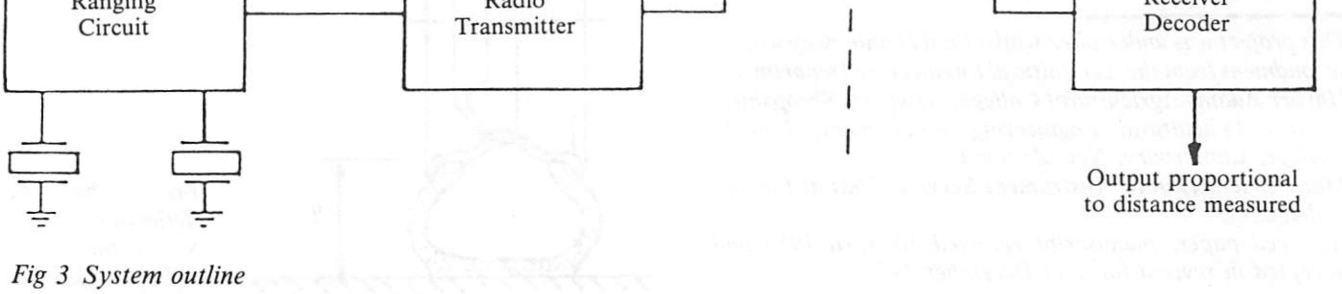


Fig 3 System outline

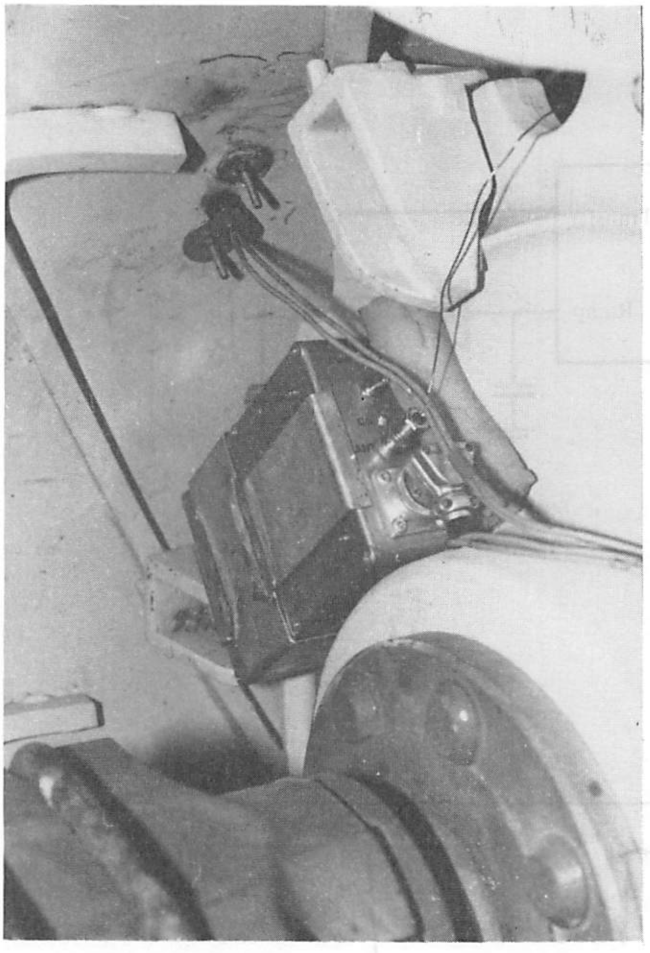


Fig 5 View of the transducer mounting through the wheel rim and ranging circuit/radio transmitter box attached to the wheel centre

with a period of 15 ms, setting the repetition rate of the transmitted pulses. This time period is significantly longer than the time taken for a sound wave to travel right around the circumference of the tyre (10–11 ms) and so the possibility of one sound wave interfering with the next after a single circumnavigation of the tyre torus is removed. The pulsed signal drives the transmitter (TX), which sends a single 10 μs pulse (fig 6b, trace 1) to the transmitter transducer. The pulse width is matched to the 40 kHz resonant frequency of the piezo-electric transducers to ensure the largest return signal possible. The matched pair of transducers are held in separate rubber mounts in a plastic frame to reduce interference to the received signal from transmitter ringing.

The transmitted signal travels at the speed of sound across the inner tube and an attenuated version is reflected back driving the receiver transducer. The resultant electrical signal is applied to a non-linear 40 kHz tuned amplifier A (fig 6a) to increase the signal to a usable level. The output for a typical reflection is shown in fig 6b, trace 2.

Initially there is a long exponential response at the amplifier output due to mechanical and acoustic ringing between the two transducers, followed by a shorter but higher pulse, the return pulse from the tube.

The return pulse is compared with a signal generated in the dead time circuit (fig 6b, trace 3) by comparator D (fig 6a). The amplifier A, comparator D and the dead time circuit together provide the signal conditioning necessary to use an ultrasonic measuring system at close range.

The dead time circuit and the comparator output (which changes state whenever traces 2 and 3 cross) are used to stop and start, respectively, the ramp generation circuit. Traces 5 and 6 of fig 6b show the logic signal used to generate the ramp and the ramp signal itself generated across capacitor C_1. Because the ramp voltage varies linearly with time, its final value is proportional to the transit time of the ultrasonic signal which in turn is proportional to the radial deflection of the tyre. The final value voltage is transferred across to capacitor C_2, prior to discharging C_1 ready for another measuring cycle. Capacitor C_2 is used to hold the voltage between measuring cycles to ensure a steady output from the ranging circuit.

Transmitter and receiving circuits

A voltage controlled oscillator, driven by the output signal from the ranging circuit produces a frequency proportional to the radial deflection. This is used to modulate an FM transmitter. The receiver-decoder demodulates the FM signal using a standard FM radio to reproduce the variable frequency signal. A 'phase-locked' loop is used as a frequency-to-voltage converter to reproduce the output voltage of the ranging circuit.

Over the range of distance measured (200–400 mm), the voltage varied from 1.0 to 2.3 V and was thus in a suitable form for recording on any standard equipment.

Transducer installation

The tyre used for prototype appraisal was an 18.4 × 34 tubed, cross-ply, drive tyre. The transducer assembly was inserted into the inner tube diametrically opposite the valve. The exact location of the transducer was determined prior to tyre and tube removal by drilling a pilot hole through the rim into the inner tube whilst the tube was still inflated at low pressure. Placement of the transducer away from the valve allowed the tube greatest freedom in taking up its desired inflated form inside the tyre without placing undue stress on the transducer assembly. The leads from the transducer were led out through a cold cure valve patch which was subsequently stuck on to the tube sealing the hole used to insert the transducer (fig 7). Two holes were drilled in the rim to accept bolts locating the transducer on the rim centreline.

The installation technique was such that the transducer

Fig 7 External view of the transducer mounting within the inner tube

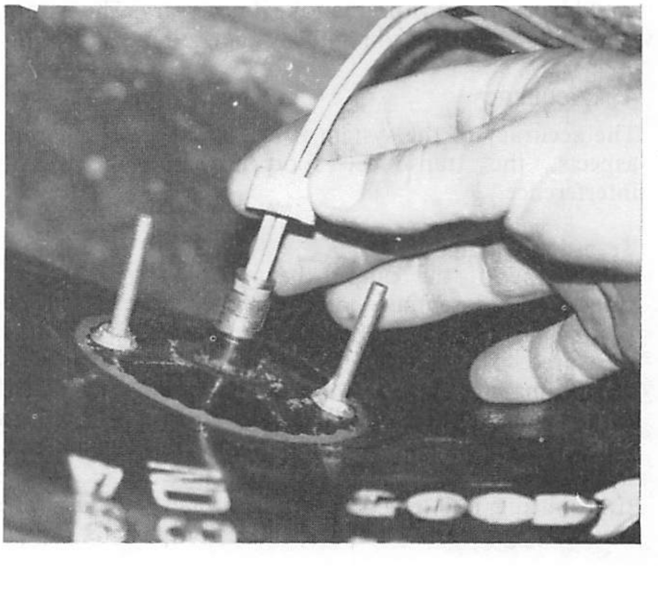
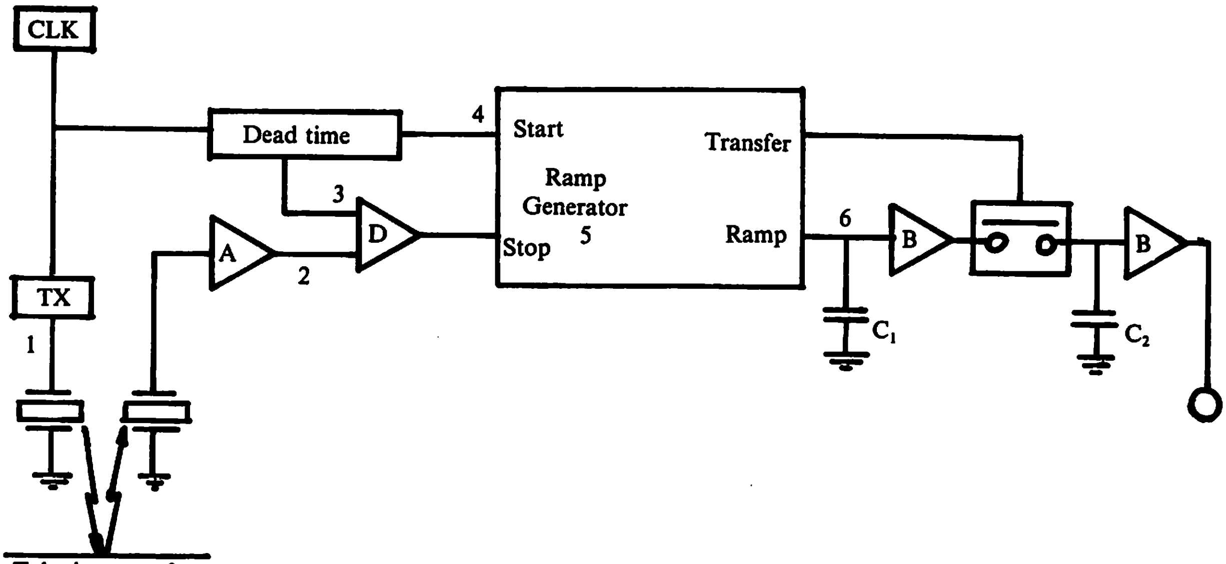
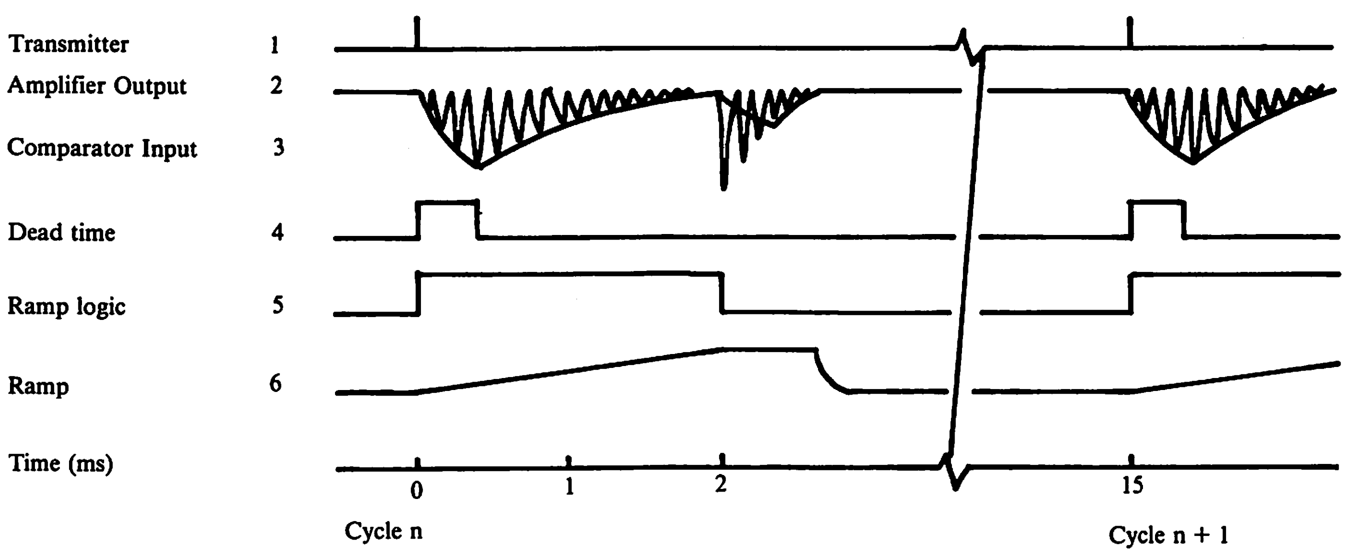


Fig 6 Ranging circuit

(a) Block diagram



(b) Timing



could be removed from the tube if necessary. The fixture was simple and proved relatively easy to render airtight.

4 Accuracy

The accuracy of the system is affected by two separate aspects, the transducer footprint and the signal interference.

Transducer footprint

The shape of the output beam from an ultrasonic transducer is essentially conical and hence the 'footprint' is circular, the diameter being determined by the distance measured. The cone angle for the transducers used is approximately 70° and over an actual distance measured of 175 mm, the resulting footprint circle is 245 mm in diameter. The receiver is capable of receiving signals from a similar cone and with a centre to centre distance of the transmitting and receiving transducers of 30 mm the intersecting area of their respective footprints is rather large, with the device scanning the tyre centreline over a length of 185 mm (fig 8).

Within the cone emanating from the transmitter, however, large variations exist in the axial pressure in front of the piston (Gooberman 1968). The actual shape of the highest intensity waves is complex and dependent on the size of the oscillating piston and the frequency of operation. It is estimated that in this application the area scanned is roughly circular and of the order of 30 mm in diameter. Bearing in mind the irregularities in tyre wear, and construction tolerances of tyres and rims, this 'area scanning' is deemed to be acceptable in this situation.

Signal interference

When measuring distances of less than 250 mm, the signal conditioning circuitry is not fully able to screen out the interference caused by the transmitter ringing. This does not cause a breakdown in the system, but reduces the accuracy of measurement as shown in table 1.

Fig 8 Reflection of the high pressure inner core within the 70° outer cones.

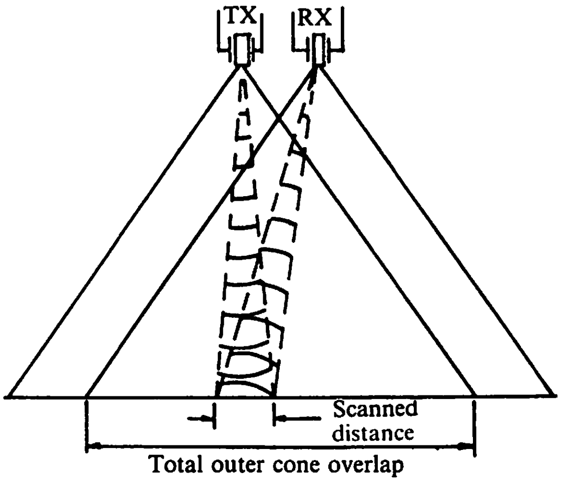


Table 1 System accuracy

Scanned distance, mm	*Error, mm*
0–150	Out of range
150–250	± 2
250–400	± 1
400+	Out of range

5 System testing

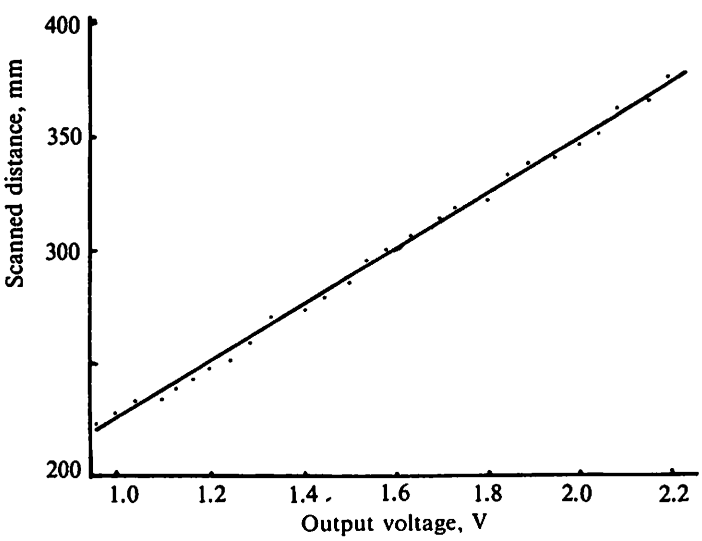
Linearity verification

A static calibration check was made using equipment similar to that described by Painter (1980). Tests were made with the transducer in the bottom-dead-centre position at a series of inflation pressures from 0.5–1.2 bar at a range of axle loadings. Within the range of radial deformation investigated, the output of the transducer was found to be linear (fig 9).

Effect of curvature of incident surface

The transducer was mounted vertically above a thin steel plate which was gradually bent into circular arcs of decreasing radii of curvature. Significant changes in the output signal were observed when the radius of curvature of the plate fell below 560 mm. The transducer produced consistent results with radii of curvature between 560 mm and infinity, and reference to tyre size data showed the device applicable, in its present form, to tyres of size 11.2 × 28 and larger (American Tire and Rim Association 1979).

Fig 9 System linearity



Dynamic testing on a rigid surface

The wheel was run on a smooth concrete surface for complete revolutions in both forward and reverse gears. Testing performed at a variety of inflation pressures between 0.5 and 1.2 bar showed the transducer output to be consistent with the statically observed deformation around the circumference of the tyre.

A typical trace (fig 10) for a single revolution of the transducers from the top dead centre position shows radial deformation to commence in the area 90–100° either side of bottom dead centre (BDC) and to reach a flat peak in the area 2–3° either side of BDC. The length, l, of the contact area (fig 11) can be evaluated by examining the function:

$$l = (r + d) \cos \alpha$$

where: r	=	rim radius	mm
d	=	radial section height at α	mm
α	=	angular displacement of the transducer from BDC	degrees
ß	=	angular displacement of end of contact patch from BDC	degrees

The function should remain constant at the value found when $\alpha = 0$ (BDC) along the contact length and then decrease as a cosine when α becomes greater than ß. The length of the contact area is then twice (r + d) sin ß. For the remainder of the circumference not in contact with the ground the radial deformation can be used directly with the value of α to define the centre line of the tyre tread.

Irregularities in the output trace were observed at either end of the contact length. These were observed to coincide with the tread bar in closest proximity to the transducer scanning area contacting and then leaving the ground. The size of the area scanned by the transducer together with the close spacing of the tread bars on the tyre carcase precluded the possibility of investigating the deformation on either a specific tread bar or between two adjacent tread bars. With tyres of a rather more open tread pattern this type of specific investigation may be possible.

6 System potential

Off-road tyre behaviour

The system in its existing form offers considerable opportunities to tyre manufacturers and researchers to investigate tyre deflection patterns in off-road situations. The ability to measure true tyre radial deflection with the tyre in a dynamic mode should lead to a greater understanding of tyre behaviour under varying levels of inflation pressure, axle loading, torque transmission and changes in working surface.

Tyre deflection control

It is generally accepted that in order to maximise tractive performance and tyre life, the radial deflection must be kept within certain limits. These differ according to the speed of operation, the load carried, the firmness of the working surface and the level of torque transmitted. In general, the higher the level of each of these variables the lower the level of deflection permissible.

The tyre manufacturers simplify these parameters by providing inflation pressures for a given size of tyre working in a given situation. This can sometimes result in as little as two advised pressures, one for road use and another lower one for ploughing/cultivation. Operators

Fig 10 *Typical output trace (inflation pressure = 0.7 bar)*

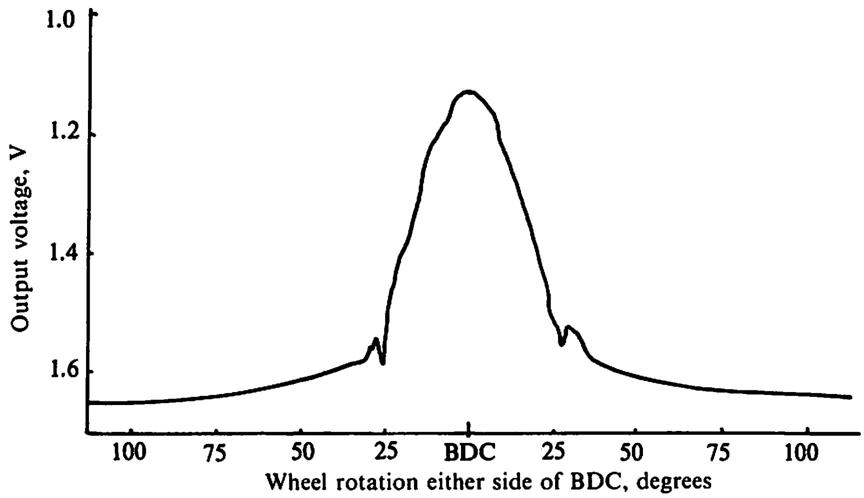
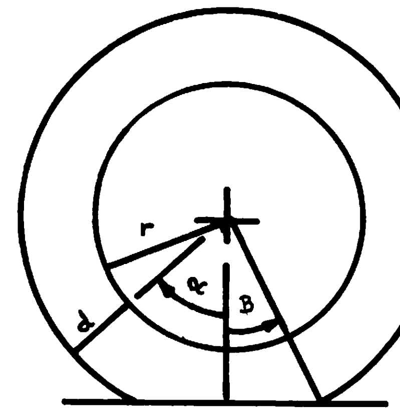


Fig 11 *Wheel geometry*



usually have no control over these values in the field and so in any cycle of daily operation, large compromises in tyre performance are made.

The use of a tyre deflection monitoring system in conjunction with a central tyre inflation system could offer relatively precise control of tyre deflection levels at preset values during a wide variety of cycles of work. If, for example, the preset value of deflection required was 15%, and a heavy implement was picked up causing this value to be exceeded, the central tyre inflation system would operate, bringing the deflection level back within acceptable limits, or warning that acceptable deflection could not be obtained beneath a specified maximum inflation pressure. The application of this type of advanced 'tyre control' system would doubtless be of benefit to agricultural tractors with their almost unique diversity of working situations. It is anticipated in the short term that users of heavy duty, high cost tyres such as those fitted to earthmoving equipment could be the first to show commercial interest in such a system.

Early warning of excessive radial deflection

As tractor weights and levels of engine power increase, operators are being given more and more potential ability to destroy tyres through excessively flexing the side walls. A simple form of the deflection system could be installed to give warning through light or buzzer of a single maximum level of deflection being exceeded. This adaptation could be made and installed cheaply in relation to the cost of new tractor drive tyres.

7 Conclusions

A system based on ultra-sonic ranging has been constructed to measure tractor drive tyre radial deflection. The output from the system is linearly proportional to tyre deflection and independent of inflation pressure. The system can be used to identify peak deflection levels at the bottom dead centre position, or, with further investigation, to define the length and form of the contact patch. A complete profile of the circumference of the tyre tread pattern can be defined.

The system offers particular potential to those interested in investigating tyre deflection in off-road situations. Potential exists for interfacing the developed system with a central tyre inflation system in order to provide automatic control of tyre deflection levels at any predetermined level, irrespective of tyre loading or working environment.

8 Acknowledgements

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The advice and assistance rendered by Roger Young, Senior Research Officer, New Zealand Agricultural Engineering Institute, and David Painter, Reader in Agricultural Engineering, Lincoln College, was particularly appreciated.

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Firing of boilers and furnaces with non-fossil fuels

J P Metcalfe

Summary

CASE studies were carried out at 10 sites using wood or straw fired furnaces on horticultural and agricultural applications. Furnace reliability was good. Refuelling was the limiting factor for unattended operation and to extend this time, burning of wood, automatic firing, and use in conjunction with conventional oil fired heating equipment was practised. Straw fuel was usually kept dry, with typical moisture contents of 13–15%. Wood moisture contents were over 20%. Combustion efficiencies mainly of the order of 40–60% were measured with simple furnaces. With automatic fired plant, mean combustion efficiencies of 71–73% were achieved.

1 Introduction

MORE than 100 years ago in 1873, straw burning boilers incorporating a mechanical straw feed were available but were not used widely. Wood and coal remained the traditional fuels for heating dwelling houses in country areas until the late 1950's when they started to be displaced by fuels which were more convenient and available at relatively low prices. By the late 1970's, increased costs of fossil fuels had led to an interest in burning wood and cereal straw in furnaces on farms. The primary use was for domestic house heating with over 60% of the furnaces used for this purpose. Approximately 25% of the furnaces were used for both house heating and agriculture which includes crop drying, shed warming and frost protection, with a further 10% purely for these agricultural applications. Little factual data are available on the quantities of these fuels used on farms at present.

It was estimated that some 70% of the furnaces are used with straw and 30% with wood; some users may burn a combination of these fuels.

Energy saving

When the potential for energy saving by burning straw or wood is assessed, allowance has to be made for the extra energy required to collect, transport and handle the material from the field or forest to the furnace. Estimates of the total energy cost for baling and carting straw indicate that this amounts to about 3% of the net energy content of the straw. If straw has to be transported by lorry a distance of 30 km, this is likely to account for only a further 1 or 2%. When allowance is made for the energy cost of subsequent handling and storage of straw on the farm, the energy balance is still very favourable if the heat content of the straw can be effectively utilised.

Economics

Assuming that the heat content of the straw can be utilised sensibly in the vicinity of production, at present the economics compared with solid fuels are likely to be favourable, provided that the straw is burned at an efficiency approaching that achieved with solid fuels. From a practical point of view, problem areas include provision of a suitable building to store the straw in a dry condition, the labour requirement associated with handling of the straw — especially from the stack into the boiler or furnace — the achievement of satisfactory combustion efficiencies, accurate control of heat output and the dissipation of heat at certain periods.

By the late 1970's, boilers designed to burn straw and wood were being installed on farms and nurseries, and prospective users were seeking more detailed information on the operational aspects mentioned above. Although some information was available from overseas, notably Denmark, little factual data were available on plant performance and problems encountered when boilers designed to burn straw or wood were installed on farms in the United Kingdom. Accordingly, in 1980, it was decided to monitor a small number of units installed specifically to provide heat for agricultural/horticultural purposes (table 1).

2 Objectives

The main objectives of the case studies were:

- identification of the main applications of non-fossil fuel fired boilers and air heaters used in agriculture;
- to gather information on fuel types, storage and handling;
- to obtain information on how non-fossil fuel burning heating plant is operated;
- to find out the levels of combustion efficiency achieved under normal working conditions when burning non-fossil fuels in simple furnaces.

Table 1 Year of installation and use

Year of installation	*Number of units*	*Use at time of visit, days (site number)*		
1978	1	683 (5)		
1979	3	800 (4)	410 (7)	210 (8)
1980	3	330 (10)	240 (6)	130 (9)
1981	2	70 (2)	100 (1)	
1983	1	70 (3)		

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3 Combustion

Combustion of baled straw, and to a lesser extent wood, takes place in three stages:

a) initial rapid combustion accompanied by flaring of the exposed surface material;
b) combustion in a gaseous phase of volatile hydrocarbons, and
c) combustion of charred material — mainly carbon.

With straw bales, the rate of combustion in the last phase is determined by the degree of packing of the charred material which in turn determines the surface area exposed to the combustion air.

During combustion, carbon monoxide and carbon dioxide are produced. Even with straw in bale form, volatilization is rapid and combustion of the volatile hydrocarbons may be completed in a short period of time. The rate at which combustion air has to be supplied during the three phases is significantly different. Most units incorporated two thermostatically controlled dampers which regulated the primary and secondary air supply to the combustion chamber and often a flue damper was fitted as well to control the draught on the unit. The primary air damper regulates the heat output while the secondary air damper controls the amount of additional air required to complete the combustion process.

As far as is known, no satisfactory arrangement which adjusts the rate of secondary air so as to achieve maximum efficiency of combustion during the different phases has been marketed.

Failure to correctly control the rate and distribution of combustion air can result in tars being deposited in the flue and chimney, high levels of carbon monoxide and low levels of carbon dioxide, all of which result in a lowering of the thermal efficiency. The inherent problems of burning baled straw can be overcome by the use of automatic stokers. In this system, the fuel firing rate is regulated according to the heat demand and the various stages of combustion occur simultaneously. Hence, similar combustion conditions can be maintained over long periods of time. A safety device to prevent the fire burning back into the straw supply is provided.

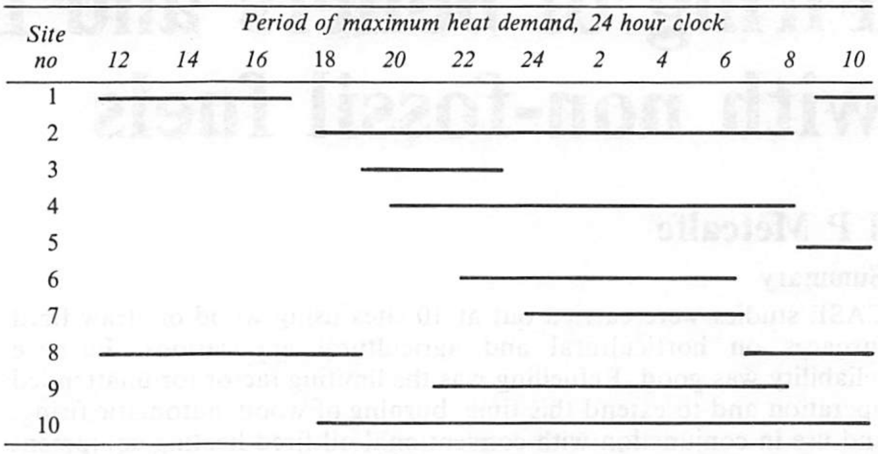
Compared with wood, cereal straw has a relatively high silica content. This has a relatively low fusion point and may form clinker in the combustion chamber. If this is not removed at an appropriate stage, efficient combustion is impaired.

Most large, single charge, straw burning units are designed to accept up to about 12 rectangular bales (750× 450× 350 mm) but some of the larger units have combustion chambers which will accommodate large, cylindrical bales which are loaded with a tractor front-end loader.

The frequency of attention necessary with manual firing depends upon the relationship between combustion chamber capacity, bale density and heat demand. When straw is used, experience has shown that, in order to sustain the rated output, frequent refuelling is necessary. In order to extend the interval between stokings during the night period, it is common practice to use timber or automatically start up a supplementary oil or gas fired boiler.

The production of bales up to about twice the density of existing ones is feasible and would extend the interval between stokings. With string-tied bales, problems of bale expansion during the initial burn period need to be explored.

Table 2 Period of maximum heat demand



4 Period of maximum heat demand

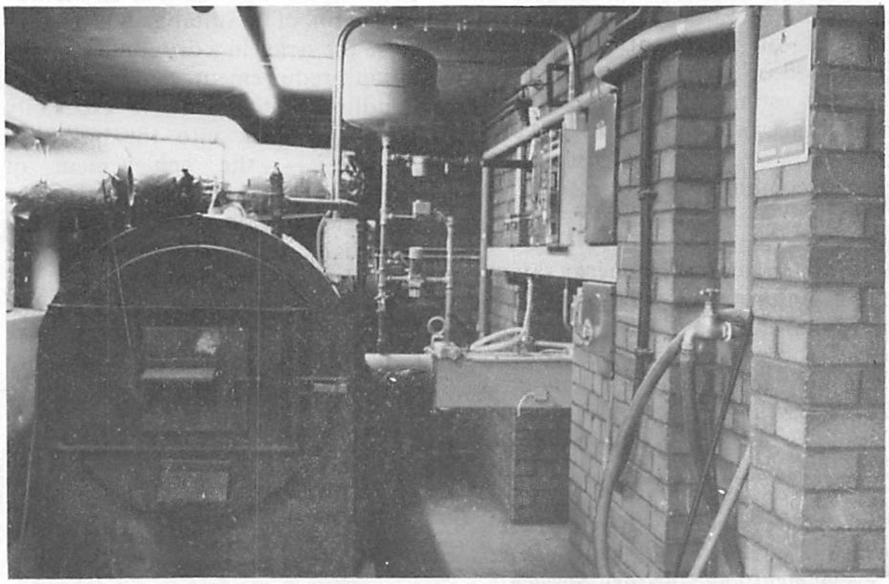
In the majority of cases where the main use of the furnace is for space heating, the period of maximum heat demand is overnight (table 2). There were three exceptions.

Site 1 —The unit is used to heat a packing shed and workshop during normal working hours.

Site 5 —This unit provides heat in a calf rearing house where staff comfort may be a prime consideration.

Site 8 —A glasshouse is heated by the furnace. This seems contrary to all expectations but could

Automatic stroking of simple straw burning boilers allows higher heat outputs to be maintained between periods of fuel supply replenishment. (Passat Heat Ltd).



be explained by the presence of an alternative heat source.

5 Applications

Glasshouse heating — 5 sites

Of these, three growers had used the straw fired furnace as the sole heat source (table 3). One site was a relatively small glasshouse. The other two sites had fully automatic straw firing and hand fired wood burning boiler designed for the fitting of auto-firing at a later date.

The other two growers used their large single charge furnaces in conjunction with an existing gas oil fired boiler plumbed into the heating circuit and gas oil fired warm air heaters, respectively, these units taking over the heating load as the charges of non-fossil fuel burned away.

These two methods, automatic firing (sites 2 & 3) or additional oil fired heating (sites 7 and 10), represent the only practical way of providing long duration controlled heating utilising non-fossil fuels.

It is noted that in the latter four cases of glasshouse heating, this is the only application for the heat souce (sites 2, 6, 8, 10). This approach allows a purpose designed system for optimum operation.

Mushroom growing room heating — 1 site

The application of a non-fossil fuel fired heating system to mushroom husbandry is similar to that of glasshouse heating. In order to overcome the problems of main period of heat demand overnight, the straw fired boiler was used in conjunction with an oil fired boiler. The oil fired unit took over the heat load as the heat output of the straw fired boiler reduced when the charge burnt down.

The presence of staff on the mushroom unit all day enabled the boiler to be stoked regularly.

Crop drying — 2 sites

Both drying applications were in storage drying. The respective crops were onions and grain. For the onion crop, warming of large volumes of air up to 30°C is required. In the first stage of drying, the air heater used was not able to maintain this temperature. When used to pre-warm air which was then further heated with a propane burner, difficulties of propane burner control were encountered. The use of the straw fired air heater was limited to the secondary drying stage in onion drying where it was able to provide enough heat to reduce relative humidities to the desired levels.

Table 3 Applications

Site no	*Crop drying*	*Greenhouse heating*	*Livestock house heating*	*Workshop heating*	*Mushroom production*	*Farmhouse heating*	*Process hotwater*
1	/			X			
2		X					
3			XP			/	
4	X	X				/	
5			XC			/	
6		/					
7					/		X
8		X					
9			XC			/	X
10		/					

X = *Sole heat source*
/ = *Partial heat source*
P = *Pigs*
C = *Calves*

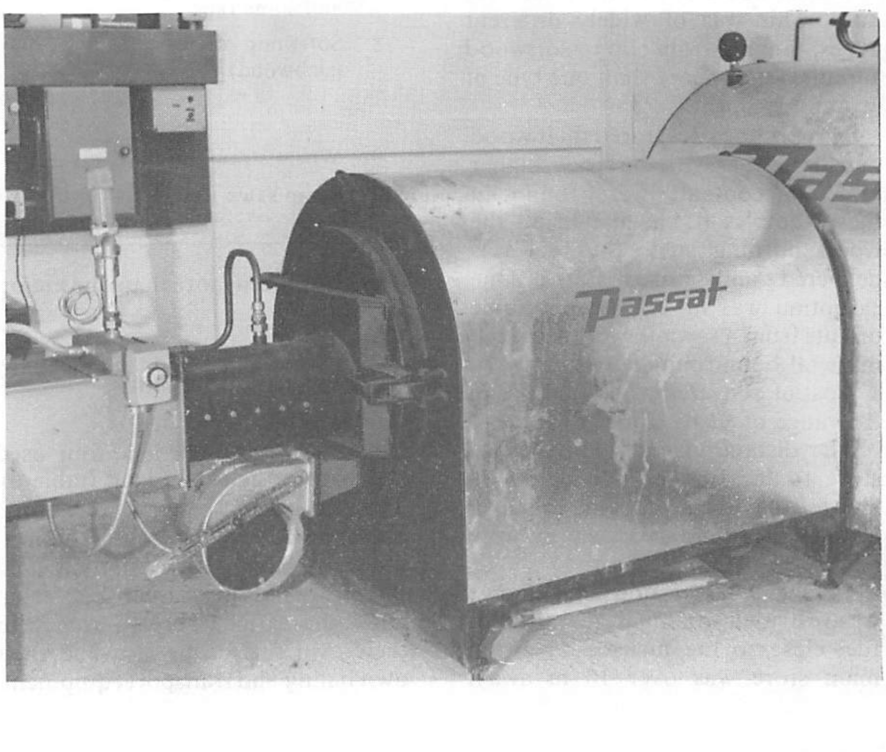
For grain drying in crop storage, additional heat is only required in the later stages of drying. On site 4, heat transfer to the drying air was by means of piped hot water to a heat exchanger.

In the later stages of crop drying, the ventilation equipment is not required to run continuously overnight. Overnight heat is not essential, and provided that staff are available for stoking, hand fired equipment for these purposes is in most cases satisfactory.

Livestock housing — 3 sites

On all sites, the non-fossil fuel fired heating system was the sole heat source. The largest heat production unit was at site 3. Heat was provided for environmental control in farrowing rooms and weaner growing rooms. Heat was essential for production and the straw fired system replaced liquid propane gas burners. The need to produce heat throughout the coldest hours of the day led to the installation of an automatic fired system. The farmer had previously owned a hand fired boiler for domestic hot water supply. The new automatic fired boiler provided water for the house.

On some larger boilers, the automatic stoking system supplies fuel to a pre-burner (Passat Heat Ltd).



At sites 5 and 9, smaller wood fired hot water systems were used for calf house heating. The relatively low heat loads and fuel type allowed stoking twice daily.

The burner at site 9 provided hot water for dairy equipment cleaning. In many cases, electricity is used to provide hot dairy washing water.

Farmhouse heating

Many farmhouses are large, and incur substantial heating costs. The attraction of a "free" fuel is considerable. Thus many agricultural applications combine house heating, the primary reason for installing the system in the first place being unclear. In some cases, the success of a domestic system has encouraged the use of the non-fossil fuel fired system in husbandry application.

6 Fuels and storage

Straw was used as a fuel on six of the sites visited (table 4). All but one used conventional bales. This was at a Ministry Experimental Husbandry Farm where compressed conventional bales were being fed at the time of the visit.

The farm using large round straw bales was the only one not to provide dry storage for the straw. This lack of provision is reflected in the high sample moisture content of the fuel in this case.

Delivered cost of the straw varied from £11 to £17 although several farms did not put any price on the fuel at all.

Wood was used as a fuel on five sites. This was of widely different types, ranging from elm to softwood offcuts. Often more than one type of wood was burnt.

Three of the sites stored their wood outside and, as with the straw, higher moisture contents were found in these samples (table 5). On all the wood burning sites, the fuel was delivered and stored loose. One exception was on site 6 where pine offcuts from a sawmill were delivered in metal bound bundles.

Cost of delivered wood fuel was in the range of £3 to £7 per tonne.

The distance from the main fuel store to the furnace was up to 30 metres, the exception being the farm where large round bales of straw were left in the field.

In several cases, additional storage was provided for small quantities of fuel close to the furnace when the main store was over 10 m away.

Table 4 Summary of fuels used

Site no	*Fuel type*	*Moisture content, %*	*Package*	*Bulk density, kg/m³*	*Delivered cost, £/t*
1	Straw	16.7	Compressed conventional bales	300	—
2	Straw	—	Conventional bales	110	17
3	Barley straw	15.0–18.0	Conventional bales	110	—
4	Barley straw	17.3	Conventional bales	110	11
5	Elm and chestnut wood	26.4	Loose	696	—
6	Elm and pine wood	22.2	Loose	693	7
7	Wheat straw	16.2	Conventional bales	133	16
8	Softwood	47.0	Loose	668	3
9	Wheat straw	43.2	Big round bales	175	—
10	Scrap sawn timber	38.9	Loose	127	3
11*	Barley straw	15.0	Conventional bales	110	24

* *Danish Agricultural Experimental Station Højer*

Table 5 Storage Facilities

Site no	*Fuel type*	*No of stores*	*Type of store*	*Store to furnace distance, m*
1	Straw	1	Lean-to next to boiler.	10
2	Wheat straw	2	Dutch barns, closed 2 sides.	4
3	Barley straw	2	The store adjacent to the boiler house is 12 m deep and 22 m wide and 4 m to eaves. It is enclosed on 3 sides with the boiler house taking one side.	0
4	Barley straw (plus some elm logs)	1	a) Large stone barns b) Stone "boilerhouse" with low headroom.	6
5	Elm and chestnut	1	Old garage.	2
6	50% dead elm 50% pine offcuts	1	Outdoors.	5 30
7	Mostly wheat straw and some rape	1	Corrugated tin roof timber lean-to.	17
8	Softwood offcuts (slabwood)	2	Mostly outside — limited storage, 30 t in block built portal frame boiler house.	0
9	Wheat straw	—	—	400
10	Scrap sawn timber	1	Random stacking open on rough ground	3–5

There was often more than one major fuel store.

7 Fuel handling and transport

Of the six straw burners, four used straw from their own land (table 6). The two others, being a greenhouse nursery and a mushroom producer, did not have large holdings and therefore obtained their fuel from adjoining farms. Those farms with their own fuel crops also had their own baling and transport equipment. In the two other cases, contract baling and handling and baling and delivery by the neighbouring farmer applied, respectively.

Handling systems from the field were (table 7):

contractor's complete mechanical bale handling system;
hand stacking for tractor mounted bale carrier;
farm trailers with manual loading;
industrial loader carrying large round bales;
farm trailers loaded by squeeze loader.

Table 6 Fuel Transport

Site no	*Fuel type*	*Source*	*Distance, km*	*Transport method*	*Load weight, t*
1	Straw	Own farm	0.1	Trailer	0.5
2	Wheat straw	Local farms via contractor	0.1–5.0	Flat 8 + 56 bale carrier	
3	Barley straw	Own farm	0.1–1.5	Farm trailer, 150 bales	2.8
4	Barley straw (plus some elm logs)	Own farm	0.5–2.0	40 bales/rear tractor mounted carrier	0.7
5	Elm and chestnut	Wind falls; removal from arable land and own wood	Within 312 ha	4 t trailer load	2.0
6	50% dead elm 50% pine offcuts	Forestry Commission sawmill	2.4 4.8	Tractor + trailer Lorry	3.0 8.0–10.0
7	Mostly wheat straw and some rape	Local farm	0.2–0.8	Farm trailers	6.3
8	Softwood offcuts (slabwood)	Local sawmill	4.0	Tractor and trailer	3.0– 3.5
9	Wheat straw	Own farm	In field as baled	2 bales on industrial loader	0.7
10	Scrap sawn timber	Pallet repairers and house demolition	5.0 (max)	Trailer towed behind estate car	0.3

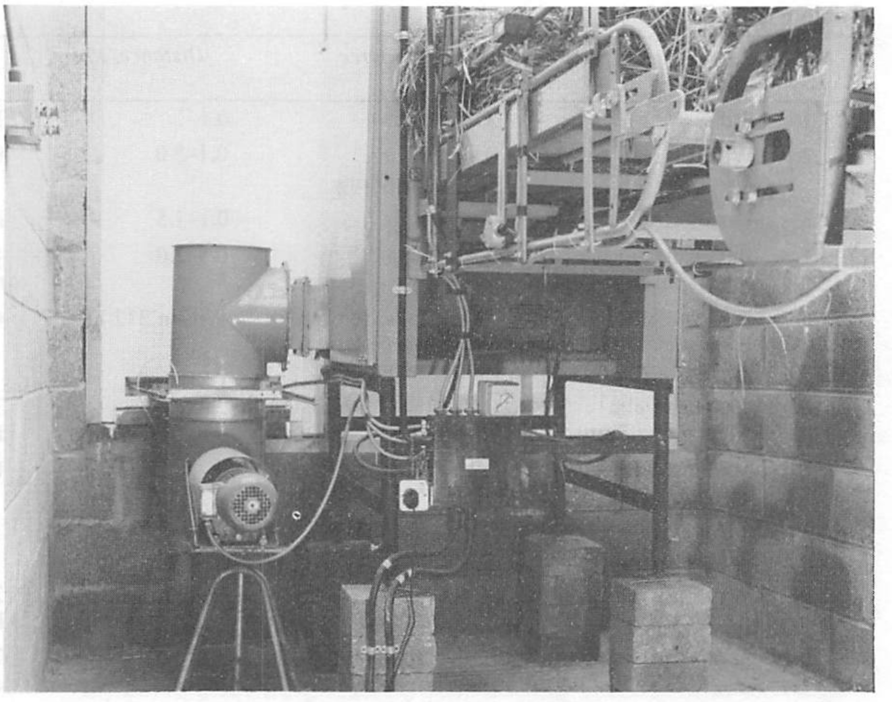
Table 7 Handling into store

Site no	*Fuel type*	*Handling method*	*Handling equipment*	*Labour, man min/t*
1	Straw	Hand	Tractor	—
2	Wheat straw	Flat 8 system 13 high; hand stacking above 13 high	Flat 8 loader + 56 bale carrier by contractor	By contractor
3	Barley straw	Bales are stored in Dutch barns around the farm. From these Dutch barns they are transported 20 at a time on a front loader to the boiler house	Front loader and muck fork	18 (20 minutes to take 60 bales into the boiler house store in 3 trips)
4	Barley straw (plus some elm logs)	a) Barns: rear mounted 40 bale carrier, restacked by hand b) Boiler house: transferred from barns on pallets, restacked by hand	a) Tractor and gripper b) Rough terrain fork lift truck	a) 46 (Estimated from FMS 28) b) 14 (Estimate)
5	Elm and chestnut	Trailer	Hand and trailer Hand from trailer to store	28 3
6	50% dead elm 50% pine offcuts	Hand Forklifted direct from lorry	Self-propelled diesel fork lift truck	(Not measured)
7	Mostly wheat straw and some rape	4 × 2 squeeze loader in tractor hand formed heaps contract baling and Dutch barn	Tractor loader and trailers	44 (Estimated from FMS 28)
8	Softwood offcuts (slabwood)	Tipped and stacked	None	30
9	Wheat straw	If field away from farm a few bales may be brought two at a time to farm.	Industrial loader	20
10	Scrap sawn timber	Trailer manually unloaded into store	None	20

The labour requirement in man minutes per tonne was difficult to estimate. Most farmers' estimates came well below those expected from Mechanization Study 28 — Bale Handling Methods. These underestimations are most likely to be attributable to ignoring the time spent in baling and other field operations. This would be reasonable if the bales were delivered by the seller of the bales and this cost was included in the price.

The above comparisons should also be borne in mind when considering the labour for handling the wood fuel. In the majority of cases, the wood is delivered by the seller and the labour requirements are only for loading into store.

In all but one case of the wood burners was anything other than manual labour used to load the fuel into store. Use of a rough terrain forklift truck was made possible by delivery of metal bound bundles of wood.



Bales of straw are shredded prior to the auger feed mechanism of automatic stoking systems. (Passat Heat Ltd).

8 Operating period without attention

Attention to the furnace was determined by the need to refuel. This was affected by the capacity of the furnace, or automatic firing conveyor, the heat load and the fuel used (table 8).

Methods used to increase the periods between refuelling were use of automatic firing, densification of straw bales, replacing straw with wood overnight, and use of supplementary oil fired heating equipment to take over the heat load as the non-fossil fuel was consumed.

Due to the variety of furnace, firing method and heat load, no clear pattern emerged as to the unattended operating periods for the different types of unit.

The difference between the length of periods for unattended operation for normal and maximum load for

Table 8 Boiler/furnace

Site no	*Furnace type*	*Rating, kW*	*Firing method*	*Draught*	*Cost of heating unit, £*	*Operating period without attention, h* — *Max load*	*Normal load*
1	Air heater	146	Hand	FD	1 450 + 900 (chimney) + 2 500 (ducting)	3 (conventional bales)	3
2	Hot water boiler	933	Continuous feed	ID/FD	32 000 (boiler + stoker)	5	24
3	Hot water boiler	300	Mechanical		12 000	9	12
4	Single pass hot water boiler	94	Hand	Natural (flaps controlled by bi-metal boilerstat)	1 480	4 (with some wood)	6
5	Single pass hot water boiler	30–47	Hand	Natural	—	12	12
6	Hot water boiler	146	Hand	Natural	2 262	8	12–14
7	Hot water boiler	73	Hand	Natural	1 300 + 550 (pipework, valves and chimney)	2 (last load 11 pm, then oil fired boiler takes over till 7 am)	4 (daytime)
8	Hot water boiler	1 450	Hand	ID	9 000	—	—
9	Hot water boiler	190	With loader	Natural & FD cut-in on thermostat	—	12	—
10	Hot water boiler	73	Hand	Natural	1 500	5	8

FD = Forced draught   ID = Induced draught

Table 9 Ash removal

Site no	Furnace type	Ash removal method	Frequency of ash removal	
			Max load	*Normal load*
1	Air heater	Hand	Daily	Daily
2	Hot water boiler	Rake to floor — cool off period — barrow to dump	Routine de-ashing when refuelling	Routine de-ashing when refuelling
3	Hot water boiler	Auger to outside the building and then hand shovelled.	Daily	Daily
4	Single pass hot water boiler	Shovel to wheelbarrow NB "Semicircular" crate fitted in boiler shell.	Twice weekly	Twice weekly
5	Single pass hot water boiler	Shovel and barrow	Weekly	Weekly
6	Hot water boiler	Scraped from combustion chamber into wheelbarrow	Weekly	Weekly, (less ash per unit fuel burned under max load)
7	Hot water boiler	Shovel and scraper	Morning and evening ie 1st and last	Same
8	Hot water boiler	Shovel	Every 4 days	Weekly
9	Hot water boiler	Farm 2000 — ash scoop on loader	Monthly	
10	Hot water boiler	Manual rake and shovel	Ash removed at each "charge" — every 5 hours max.	Every 8 hours

hand fired, large single charge boilers was typically two to one.

9 Ash removal

Ash removal was not limiting on the period of unattended operation of the boiler (table 9). The frequency of ash removal varied from five hours in the case of automatic straw firing (site 2) and manual wood firing (site 10) and one month for a large round straw bale furnace (site 9).

Where ash removal was carried out at intervals of greater than one day, this took in periods of normal and maximum heat load, so producing no variation between operations under these conditions. In some cases, de-ashing was carried out routinely with each refuelling. In this case, increased frequency of refuelling due to heat load is reflected in the de-ashing.

With efficient burning, the completeness of combustion is important. Combusted material left in the ash represents lost energy. In large, single charge, hand fired boilers, attempts to make the charge last longer, by reducing the air supply, are made. This gives a smaller fire and reduces the completeness of combustion. Thus, in the furnaces of this type, the amount of combustible material left in the ash is variable.

The use of automatic firing gave a more constant supply of fuel so that the flame was more stable and combustion was more complete.

With automatic fired furnaces, the fire temperatures were high enough to cause fusion of the ash forming clinker. Normally temperatures of 900°C are required for this to occur with straw ash.

10 Maintenance

With the large single charge boilers burning wood or straw, deposits of tar built up on the inner surfaces of the heat production unit, particularly when the air supply was restricted to make the charge last longer (table 10).

Problems were encountered on four of the sites. The usual method of removal was by firing the furnace hard occasionally, in order to burn off the deposits.

On automatic fired units, the better air supply and high furnace temperature achieved by refractory linings and pre-burners allowed more complete combustion of the volatiles driven off from the fuel.

In addition to burning off deposits, it was necessary to clean off residues from the inside of the boiler. The more sophisticated the heat exchange surfaces, the greater the cleaning requirement.

The frequency of the cleaning operations varied from one week for the small tube multi-pass boilers to four weeks for the single pass units. Depending upon access facilities, either shovels or purpose-made hoe-type scrapers were used to remove deposits.

Fly ash from the furnace is carried over into the fire tubes of the more sophisticated boilers. This was regularly removed at weekly intervals by brushing. One of the automatic fired boilers observed was fitted with automatic de-ashing screws in each of the fire tubes.

The simple, large, single charge boilers had required few repairs or modifications. Typical modifications were the addition of induced draught fans to improve combustion and addition of a grate to facilitate ash removal. Repairs were needed to the refractory lining on the inside of the furnace door. One unit required a new furnace door for this reason.

The air heater at site 1 was fitted with a hood and chimney to extract smoke escaping from the furnace door from the boiler house.

The two automatic fired boilers both suffered failures early in their life. The boiler at site 2 required replacement of the ceramic arch furnace lining with refractory brick. At site 3, this boiler suffered failure of the joining plates between the pre-burner and the boiler furnace. Also modifications to the bale conveyor were required to keep the bales on the track at corners. Production of shorter bales at the next harvest was expected to avoid this difficulty.

Other than early problems, all the

Table 10 Maintenance

Site no	Cleaning frequency	Duration of cleaning operation, mins	Modifications or repairs	Time out of commission
1	Daily — morning	60	Addition of flue to take away smoke escaping from door	Nil
2	Daily (dusting & vacuuming) Weekly Monthly	30 30 (for two people) 30 (for one person)	Ceramic arch in furnace replaced soon after installation	Nil (Apart from first 3 weeks)
3	Daily (kiln) Weekly (tubes)	3 15	Plates between kiln and furnace failed	
4	Every 4 weeks	2–5	Minor modifications for straw burning: homemade grate for ash to fall through. Replaced annually.	Nil
5	Weekly	2	None	Nil
6	Every 4 weeks	30 (including heating time)	Door replaced (free of charge) due to failed lining. Improvements made to heat dissipation control.	Nil
7	Weekly Monthly (flue)	30 15	Minor repairs: patching of cracks in fire bricks in door.	Nil
8	Weekly	30	Modified with ID fan. Autoboiler modified by manufacturer for hand firing	Nil
9	Monthly	15	None	Nil
10	Every 2–4 weeks	60	None	Nil

boilers had had little (less than 0.2% of total usage time) or no time out of commission due to repairs.

11 Control of heat output

Control of heat output was effected by control of draught. In some induced draught boilers, bi-metallic strips operating the damper flaps through chains and levers were employed. The setting of the flaps was done manually to match the overall rate of burning required.

Other methods of heat output control on hand-fired furnaces employed forced and induced draught fans on air or water temperature thermostats.

In one case, a thermostatically controlled modulating flap was used in conjunction with high water temperature cut out on the fan.

With automatic firing, a high/low/off operation of the stoking equipment was activated by a hot water thermostat. A constant rate of air supply was used when the stoker was running. On the other automatic firing system, the forced draught fan was controlled on-off by the water temperature thermostat. The maximum rate of introduction of bales of straw into the boiler was set manually. The introduction of bales was suspended when the set water temperature was exceeded. A 3 minute time delay was employed before more fuel was introduced after the water temperature had fallen below the thermostat setting.

Heat dissipation had not presented any problems on the sites visited. One site dumped surplus heat into the domestic hot water system, which was permanently connected to the main circuit. At the first automatically fired site the grower had considered adding an insulated storage tank to the system. This would have the advantage that it could be used to give rapid response to sudden heat loads.

12 Efficiencies

Combustion efficiencies have been calculated from first principles for wood and straw fuels. Included in this calculation are the effects of carbon monoxide production and the thermal capacity of the moisture content of the fuel. Flue gas temperature and composition and the calculated combustion efficiencies are shown in table 11 and 12. A summary of the theory is in Appendix.

Where carbon monoxide concentration was not measured, results were calculated as zero.

1 The combustion efficiencies obtained with large, single charge furnaces varied from as low as 26.5% up to 72.1%. Sites 1 and 5 have been omitted from this statement due to lack of CO compensation. The bulk of efficiencies lie in the range of 40–60%. The very low efficiencies were produced by the high moisture content of the fuel sample. It would be unrealistic to assume that the whole of the charge was of 43.2% moisture content.

2 In several cases, there were large variations (10–20%) in combustion efficiencies as the fuel charge was burnt down. This could have been the effect of a constant air supply to a charge which is reducing in size.

Ignition air supply may be optimum but will become excessive towards the time for refuelling.

3 Difficulties were encountered when measuring flue gas temperature and composition as a result of fluctuating air supply produced by the draught control system employed. This applied both to on-off forced draught fans and natural draught.

4 As expected, the efficiencies for automatic fired boilers were better

Table 11 Wood fired boiler efficiencies

	Flue temp, °C	*CO,* %	CO_2, %	*Efficiency,* %
Site 5				
15 mins after ignition	254	4.4	5.0	48.7
Midway through firing	280	2.5	5.0	50.3
15 mins before refuelling	119	1.0	4.5	71.0
Site 6				
15 mins after ignition	366	3.3	7.5	52.8
Midway through firing	345	1.5	6.0	52.6
15 mins before refuelling	329	1.1	4.0	42.8
Site 8				
Midway through firing	130	0.6	8.5	72.1
Site 10				
15 mins after ignition	260	3.5	10.5	60.0
Midway through firing	215	2.0	9.0	64.0
15 mins before refuelling	170	1.8	4.5	57.1

Table 12 Straw fired boiler efficiencies

	Flue temp, °C	*CO,* %	CO_2, %	*Efficiency,* %
Site 1 - Normal bales				
60 mins after ignition	107	NR	8.0	83.7
Midway through firing	222	NR	4.4	59.8
15 mins before refuelling	230	NR	9.9	74.4
Site 1 - High density bales				
100 mins after ignition	341	NR	7.6	58.9
Midway through firing	267	NR	7.2	65.6
15 mins before refuelling	148	NR	3.0	64.8
Site 2				
Midway through firing — High stoke	284	NR	13.4	74.6
(automatic) — Low stoke	255	NR	9.1	71.4
Site 3				
Midway through firing (automatic)	230	0.1	8.0	71.2
Site 4				
15 mins after ignition	318	1.1	4.0	35.9
Midway through firing	288	0.6	4.0	42.1
15 mins before refuelling	92	0.2	1.0	52.3
Site 7				
15 mins after ignition	269	0.1	5.0	55.5
Midway through firing	253	0	3.0	39.7
15 mins before refuelling	92	0.1	1.5	65.0
Site 9				
15 mins after ignition	346	4.9	8.8	38.0
Midway through firing	446	2.1	6.5	26.5
15 mins before refuelling	280	3.0	7.3	42.9

NR = not recorded

than those obtained with large single charge boilers on straw. Exceptions to this were recorded. These could be accounted for by (3) above and in the case of site 1 where carbon monoxide was not measured.

5 In some cases, very high flue gas temperatures were recorded. This would indicate that there is insufficient heat transfer through the boiler or heater surfaces. When a large charge is burning, it is not unexpected, due to the simple design of many of the burners. High flue gas temperature did reduce the problems of tarring up in the boiler. On single charge boilers with lower flue gas temperatures (sites 4, 8, 10), tar build up was reported.

6 As expected, automatically fired furnaces achieved higher combustion efficiencies. Readings of 71.2–74.5% were obtained. These levels of combustion efficiency as defined in the Appendix are approaching but not as good as efficiencies of conventional solid fuel boilers which are 80–83% on the same basis.

13 Fire precautions

These are summarised in Table 13.

Table 13 Fire precautions

Site	*Fire precautions*
1	Fuel placed for storage near boiler in small lots.
2	Fireproof wall between straw store and boilerhouse. Automatic fire sensors. Guillotine on stoker mechanism. Automatic dousing with water.
3	Fireproof wall between bale house and straw store.
4	Straw stored >4 m from fire and water bucket constantly available. Cleanliness of boilerhouse by frequent sweeping.
5	Floor of boilerhouse swept and kept free from straw particles.
6	Fuel stored in open outside boilerhouse.
7	No precaution taken. Fire risk not considered.
8	50 000 gallon water tank adjacent to boilerhouse. Fire brigade advice sought.
9	No risk. No precautions.
10	Loose stack at risk from vandals and/or arsonists — guard dogs.

14 Conclusions

1 Non-fossil fuel furnaces have been reliable with few failures.

2 Refuelling was the limiting factor after attention to the boiler.

3 Wood firing allows longer unattended periods than with straw. However, the use of compressed bales of straw will allow furnaces to remain unattended for several hours.

4 Large, single charge boilers are not able to maintain steady heat output if left unattended to burn overnight. As the highest heat demand on heating applications is during the hours of darkness, they cannot be used on these applications with complete success. The penalties of not maintaining the desired temperature should be considered before reliance upon this type of heater as a sole heat source.

5 Hand fired, non-fossil fuelled boilers were used successfully on overnight heating applications, in conjunction with automatic heating equipment, eg oil fired boilers.

6 Automatic firing allows a steady heat output for overnight heating applications. The limiting factor for attention in these cases was the capacity of the bale storage unit and feed conveyor.

7 Straw fuels are mainly in the moisture content range 15–18%. Wood fuels contain more moisture and have over 20%

moisture content. It was possible to burn material both wood and straw over 40% moisture content in large single charge furnaces.

8 Handling of straw fuel is easily mechanized. Wood fuel was handled mainly by hand.
9 The cost of straw as a delivered fuel, where this was bought, was greater than for wood.
10 Reduction of air supply to prolong burning reduced efficiency of combustion and gave problems of tarry deposits on the heat exchange surfaces.
11 Efficiencies of single charge, hand fired furnaces are much lower than those obtained with conventional, oil fired heat production units.
12 Automatic firing enables non-fossil fuels to be burnt at a combustion efficiency in the order of 70–75%.

Acknowledgements

The Agricultural Development and Advisory Service is much indebted to the farmers and growers who provided facilities for the case studies; without their co-operation the investigation could not have been carried out.

Thanks are also due to Mr P Pearson of Wolverhampton Polytechnic for his help with calculation of combustion efficiency.

Appendix Calculation of combustion efficiency with non-fossil fuels

Using a standard boiler efficiency test kit, flue gas temperature and carbon dioxide or oxygen content are measured and used to calculate the efficiency. For conventional fuels of low moisture content, the effect of incomplete combustion and carbon monoxide production is neglected.

Non-fossil fuels contain considerable amounts of water. In addition, being a cheap fuel, non-fossil fuels are burnt mainly in relatively crude furnaces where incomplete combustion produces quantities of carbon monoxide.

The presence of water in the fuel represents losses due to content heat and the thermal capacity of water and steam as it is heated to the flue gas temperature. Carbon dioxide accounts for losses mainly due to the calorific value of the gas which is lost. For the temperatures from 125°C to 250°C, each percent of carbon monoxide represents approximately 3 per cent reduction in efficiency.

The use of efficiencies derived from fuel as fired, enables direct comparison of efficiencies and unit heat cost for non-fossil fuels with those obtained using conventional methods for fossil fuels. The method of calculation of combustion losses for wood and straw fuels takes into account the effect of moisture in the fuel and carbon monoxide production.

The theory for calculation of efficiencies is given below.

x = H_2O in fuel as fired (by mass), %
y = C in dry fuel (by mass), %
z = H_2 in dry fuel (by mass), %
a = CO in dry flue gas (by volume), %
b = CO_2 in dry flue gas (by volume), %
c = O_2 in dry flue gas (by volume), %

1 Obtain amount of H_2O in waste gases

No of moles of H_2O per kg of fuel (as fired) $= e = \dfrac{(100-x)z}{2000} + \dfrac{x}{1800}$

2 Obtain amount of waste (dry) gas

No of moles of dry flue gas produced per kg of fuel (as $= K = \dfrac{(100-x)\,y}{1200\,(a+b)}$

3 Obtain amount of each dry product

No of moles of each constituent/kg of fuel as fired is obtained

Moles of CO = nCO = a k/100

Moles of CO_2 = nCO_2 = b k/100

Moles of O_2 = nO_2 = d k/100

Moles of N_2 = nN_2
= (100–a–b–d) k/100

4 Obtain stack losses due to each constituent

Flue gas temperature, °C =

Product	*No of moles per kg of fuel as fired (n)*	*Energy loss, MJ/mole (h)*	*Stack loss of fuel as fired, MJ/kg (n × h)*
CO	nCO =	hCO =	nCO × hCO =
CO_2	nCO_2 =	hCO_2 =	$nCO_2 \times hCO_2$ =
O_2	nO_2 =	hO_2 =	$nO_2 \times hO_2$ =
N_2	nN_2 =	hN_2 =	$nN_2 \times hN_2$ =
H_2O	e =	hH_2O =	e × hH_2O =
Due to unburnt CO	nCO =	CV of CO = 283.1	nCO × 283.1 =
			TOTAL =

CV = Calorific value

The total represents the complete stack losses measured above a datum (ie ambient) temperature of 25°C — this is the International Standard. The only losses ignored are losses due to sulphur in fuel and moisture in the combustion air.

5 Percentage stack loss & boiler efficiency

The foregoing method gives the total stack loss in MJ/kg of fuel *as fired* (ie H_2O in fuel is taken into account).

This can be expressed as a percentage stack loss as follows:—

$$\text{Stack loss, \%} = \frac{\text{Stack loss of fuel as fired, MJ/kg}}{\text{CV of fuel as fired, MJ/kg}} \times 100$$

$$= \frac{\text{Stack loss of fuel as fired, MJ/kg}}{\text{CV of dry fuel, MJ/kg} \times \dfrac{(100-x)}{100}} \times 100$$

where x = % H_2O in fuel as fired (by mass).

This percentage stack loss is therefore identical to the other which is often quoted:—

$$\text{Stack loss, \%} = \frac{\text{Stack loss of dry fuel, MJ/kg}}{\text{CV of dry fuel, MJ/kg}} \times 100$$

Overall Boiler Efficiency can be expressed as:—

Efficiency = 100 – (stack loss, % + other losses, %)

Other losses are:
1 unburnt carbon in ashes (see table on next page)

2 loss of heat to ashes when raking out;

3 radiation losses from the boiler.

These losses are difficult to measure, although percentage combustibles in the ash gives an indication of 1.

These losses amount to 4–5% (in total) for a small boiler. If these are not included in the calculation of efficiency, then the expression becomes:—

Efficiency, % = 100 — Stack loss, %

Note:

Calorific value (CV) straw = 17.00 MJ/kg dry fuel
Calorific value (CV) wood = 18.65 MJ/kg dry fuel
(Correct for all woods ± 1%)

Table I Analysis of fuel ash

Site no	*Fuel type*	*Incombustible fraction in ash, % DM*	*Firing equipment*
1	Straw bales	87.6	Hand
2	Conventional straw bales	98.9	Automatic screw
3	Conventional straw bales	—	Automatic whole conventional bale
4	Conventional straw bales	70.6	Hand
5	Wood	67.8	Hand
6	Wood	73.6	Hand
7	Conventional straw bales	96.5	Hand
8	Wood	85.7	Hand
9	Straw	98.0	Tractor loader
10	Wood	88.1	Hand
11*	Straw	88.9	Automatic whole conventional bale

* *Boiler observed at Danish Agricultural Research Station*

Comparison of ventilation rates in commercial pig houses as determined by four methods.

P G Carney and V A Dodd

Summary

VENTILATION rates were measured in 14 pig houses on three occasions by the carbon dioxide, heat and moisture balance equations and in accordance with BS 5925 (1981). The ventilation rates as determined by the moisture balance were in good agreement with those measured by the heat balance. The ventilation rates as determined by BS 5925 were 54% less than those calculated by the heat and moisture balances. The results of the ventilation rates calculated by the carbon dioxide balance were 25% lower than those calculated by the heat and moisture balances. Estimates of ventilation rates prevailing, based on carbon dioxide measurement, are easy and quick and are considered useful for both the pig producer and the agriculture adviser.

Notation

A = building fabric area per pig, m^2
A_i = area of inlet opening per pig, m^2
A_o = area of outlet opening per pig, m^2
A_l = area of opening per pig, m^2
A_b = is such that: $\frac{1}{A_b^2} = \frac{1}{A_i^2} + \frac{1}{A_o^2}$
c = specific heat of air, kJ kg^{-1} K^{-1}
C_d = discharge coefficient = 0.61
C_p = surface pressure coefficient
ΔC_p = difference between two values of C_p
CO_{2i} = internal carbon dioxide concentration, % by volume
CO_{2e} = external carbon dioxide concentration, % by volume
g = acceleration due to gravity, m/s^2
H = height between openings, m
H_o = height of opening, m
H_s = sensible heat production per pig, W
H_t = total heat production per pig, W
H_l = latent heat production per pig, W
k = moisture pick-up factor
Q = volume flow rate of air per pig, m^3/s
T = temperature of pig house, K
ΔT = temperature difference between inside and outside, K
U = thermal transmittance of the building, W m^{-2} K^{-1}
U_r = reference wind speed, m/s
w_i = absolute humidity of internal air, kg/kg dry air
w_e = absolute humidity of external air, kg/kg dry air
ν = specific volume of air, m^3/kg dry air
ρ = density of air, kg/m^3

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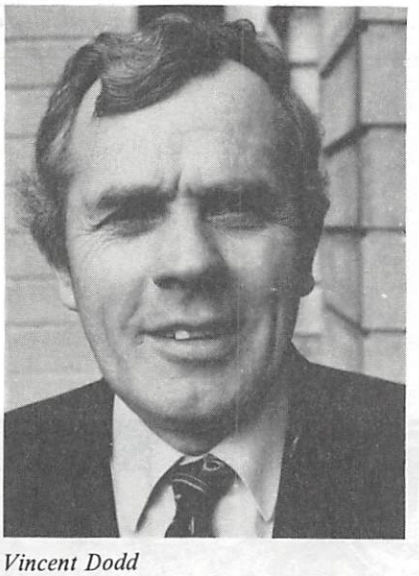
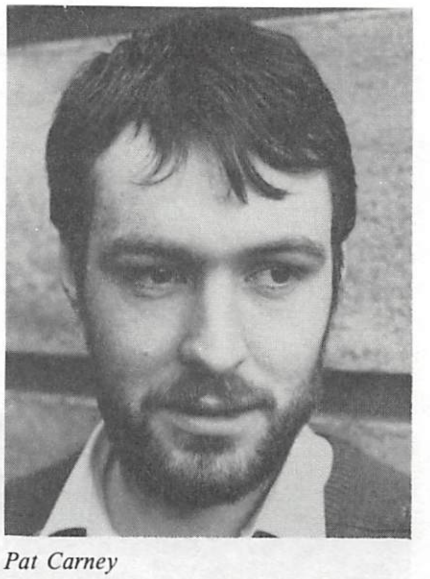


Vincent Dodd



Pat Carney

Table 1 Total and latent heat production from pigs (Bruce 1981).

Liveweight, kg	*Thermoneutral heat production (sensible + latent heat), W*				*Latent heat production, W*	
	Feed level (× of maintenance) 1	*2*	*3*	*4*	*Lower critical temp*	*Upper critical temp*
1	7.4	9.3	11.1	13.0	0.7	3.3
5	21	27	32	38	2.2	9.8
10	34	42	51	59	3.7	15.6
20	48	65	82	98	6.3	25
40	71	107	133	158	11.5	39
60	110	142	173	195	17.1	52
80	136	172	207	243	23	63
100	161	198	236	274	30	73
140	207	259	311	363	44	91
180	250	313	373	438	60	108

Introduction

In studies of pigs housed under commercial conditions ventilation rates must be determined in order to investigate the prevailing environment and animal health. This study was undertaken with the objective of comparing the ventilation rates as determined by the carbon dioxide, heat and moisture balances and also by the methods detailed in BS 5925 (1981). Fourteen commercial pig houses were chosen for this study. The following parameters were measured in each house type on three occasions simultaneously: (1) internal wet and dry bulb temperatures; (2) external wet and dry bulb temperatures; (3) external and internal carbon dioxide concentration; (4) number and weight of animals; (5) ventilation opening areas; (6) wind speed; (7) supplementary heat where appropriate. The building fabric area and thickness were measured, while the building materials used in the construction and feed levels were noted. The ventilation openings were all rectangular in shape.

Wet and dry bulb temperatures were measured using a whirling hygrometer (Casella). Carbon dioxide concentration was measured with Draeger tubes. Wind speed was recorded using a rotary vane anemometer.

The total, sensible and latent heat production values are taken from Bruce (1981) and are summarised in table 1.

The ventilation rate was calculated on each occasion by the following methods:— (1) heat balance (2) moisture balance with and without a moisture pick-up factor (3) carbon dioxide balance (4) BS 5925 (1981).

Heat balance:

$$H_s = (\Sigma A U + Q \rho c)\Delta T$$

Moisture balance:

$$Q = \nu k(0.41\times10^{-6})H_l/(w_i - w_e)$$

Carbon dioxide balance:

$$Q = (45\times10^{-9})H_t(100)/(CO_{2i} - CO_{2e})$$

BS 5925:

Ventilation due to temperature difference only,

single opening:

$$Q = \tfrac{1}{3} C_d A_1 (g\Delta T H_o/T)^{0.5}$$

two openings separated by a height H:

$$Q = C_d A_b (2 g \Delta T H/T)^{0.5}$$

Ventilation due to wind only:

$$Q = C_d A_b U_r (\Delta C_{\bar{p}})^{0.5}$$

Results and Discussion

The results of the determined ventilation rates are shown in table 2. The flat deck and McGuckian houses were fan ventilated and hence BS 5925 equations are not applicable to them and it was not possible to measure the supplementary heat in the oil-heated flat deck. The results of ventilation rates calculated by the moisture balance with pick-up factor are in good agreement with the heat balance results. The moisture pick-up factor is the factor by which the moisture production of the pig must be multiplied by to take account of the moisture taken up by the internal air from the slurry and the feed. The moisture pick-up factors were calculated by comparing daily heat and moisture balances in each house type over

Table 2 Ventilation rates as determined by the carbon dioxide balance, heat balance, moisture balance and BS 5925 (1981) in 14 commercial pig houses on three different days

House type	*Date in 1983*	*Volume flow rate of air m³/s/pig*				
		by carbon dioxide balance	*by moisture balance without pickup*	*by moisture balance with pickup*	*by heat balance*	*by BS 5925*
Farrowing						
Side creep	18/2	0.284	0.184	0.295	0.314	0.141
	23/2	0.100	0.076	0.121	0.108	0.072
	3/3	0.142	0.101	0.161	0.172	0.082
Forward creep	14/2	0.180	0.121	0.168	0.242	0.087
	22/2	0.060	0.078	0.110	0.058	0.077
	1/3	0.123	0.132	0.185	0.149	0.072
Weaning						
Flat deck (gas heated)	18/2	0.104	0.095	0.133	0.128	—
	23/2	0.079	0.063	0.089	0.105	—
	3/3	0.092	0.074	0.104	0.126	—
Flat deck (oil heated)	18/2	0.522	0.451	0.721	—	—
	23/2	0.491	0.339	0.542	—	—
	3/3	0.371	0.242	0.387	—	—
Solari	15/2	0.031	0.027	0.054	0.043	—
	22/2	0.025	0.019	0.038	0.035	—
	1/3	0.035	0.022	0.044	0.051	—
Rearing						
Kennel 1	14/2	0.031	0.040	0.064	0.061	0.025
	22/2	0.037	0.031	0.050	0.067	0.027
	1/3	0.035	0.023	0.037	0.037	0.017
Kennel 2	15/2	0.053	0.051	0.071	0.063	0.024
	22/2	0.057	0.045	0.063	0.064	0.021
	1/3	0.054	0.051	0.071	0.096	0.091
Large flat deck	18/2	0.243	0.352	0.490	0.466	0.103
	23/2	0.419	0.432	0.590	0.512	0.091
	3/3	0.652	0.550	0.770	0.715	0.085
Verandah 1	17/2	0.034	0.031	0.040	0.038	0.022
	23/2	0.037	0.035	0.045	0.042	0.019
	2/3	0.031	0.026	0.034	0.033	0.018
Finishing						
Verandah 2	17/2	0.158	0.140	0.210	0.209	0.059
	23/2	0.082	0.068	0.102	0.095	0.042
	2/3	0.142	0.080	0.120	0.184	0.080
McGuckian	17/2	1.850	0.779	1.636	2.000	—
	23/2	1.742	0.893	1.875	1.942	—
	2/3	3.340	1.300	2.730	2.940	—
Trowbridge	15/2	0.215	0.139	0.278	0.340	0.305
	22/2	0.272	0.152	0.304	0.281	0.295
	1/3	0.165	0.168	0.336	0.316	0.305
Dry sow						
Dry sow 1	10/2	2.870	1.740	2.090	2.120	5.530*
	23/2	1.800	1.810	1.920	1.870	0.671
	2/3	1.680	1.940	2.330	2.230	0.572
Dry sow 2	14/2	1.380	2.080	2.500	2.170	2.770
	22/2	0.770	0.900	1.080	1.080	0.680
	1/3	1.530	1.480	1.780	2.170	1.170

**Wind based ventilation*

approximately a two months recording in another study (Carney 1983) and varied from 1.2 to 2.0. The results obtained by the BS 5925 (1981) equations for ventilation due to temperature only are 54% less than those calculated by the heat and moisture balances. Bruce (1977) showed that at low ventilation rates the flow of air changes from turbulent to laminar flow and therefore the discharge coefficient is not equal to 0.61. This is a possible reason for the low values of ventilation rate. Also the few tests carried out at higher ventilation rates show better agreement of the BS 5925 with the heat and moisture balances, eg dry sow house no 2 on 14/2/83. In addition, air infiltration through the building fabric would also lead to the difference between BS and the other methods. The BS 5925 (1981) equation for ventilation due to wind only was applicable only once and gave a value of approximately twice the other methods.

The results of the ventilation rates calculated from carbon dioxide balances are 25% lower than those calculated by the moisture and heat balances. These suggest that the value for carbon dioxide production given by Bruce (1981) and Van de Velde (1981) of $45 \times 10^{-9} m^3 s^{-1} w^{-1}$ of total heat may be somewhat low. If the above figure was increased by 25%, there would be good agreement with the moisture and heat balances. The ventilation rates presented here are based on total, sensible and latent heat values taken from Bruce (1981), see table 1. These values are however daily averages and may vary within the day, eg before and after eating.

It is concluded that the ventilation rate as measured by carbon dioxide concentration is a very quick and easy method of measuring the ventilation rate prevailing in a building. There is potential for this method to be used by advisers for checking the ventilation rate in existing houses.

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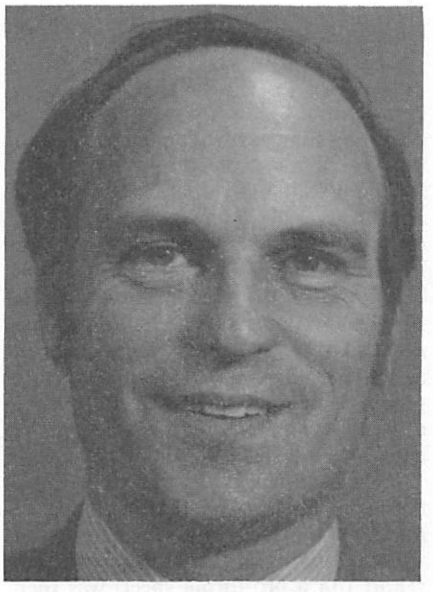
Wise investments for potato growers

T Gould

THE pressure is on to improve the quality of potatoes with some stores insisting that deliveries be temperature controlled and delivered in insulated lorries during the summer months. Baking potatoes are big business and closely graded stocks could command a premium price of 3 to 3½ times that for ordinary ware samples but large main crop potatoes are required all year. On the seed side, controlled ageing is being shown to give better crop yields whilst a serious commercial risk attaches to the use of sprout suppressants, the use of which can be avoided by good storage. In fact, all these requirements point to the need for good quality ventilated or indeed refrigerated storage and we need to overcome the immediate reaction from growers against high capital and running costs. As Engineers, we have to try and balance the capital and running costs against the benefits which these can give and this is an area in which Electricity Board Agricultural Advisers can help.



Running costs can be reduced by making use of day/night electricity tariffs. All Electricity Boards offer tariffs which give 7-8½ hours during the night time (between 11.00 pm and 7.30 am GMT — an hour later in Summer) at a substantially reduced unit rate. The tariff is most often called "Economy 7" or perhaps "White Meter Economy". The basic charges increase slightly compared with the normal tariffs and daytime electricity usually costs a little more, but these small increases can quickly be offset by the savings made when using the cheaper night units.

Changing to the "Economy" tariff is normally free of charge, by applying to the local Electricity Board. A dual rate meter is installed so that all the electricity used on the farm during the cheap rate period is recorded on one dial and charged at say 1.94 pence per unit. Electricity taken outside these hours is recorded on the other dial and charged at say 5.4 pence per unit, rather less in Scotland. Table 1 illustrates the effect of adopting the "Economy" tariff for potato storage, it being quite feasible to halve running costs.

Obviously in advising on the use of "Economy" tariffs, it is important to look at the total electricity consumption on the farm but there are other areas where considerable savings can be made. A typical dairy farm would show 15% savings simply by adopting the "Economy" tariff. Savings can be considerably enhanced by heating all hot water required for cleaning and udder washing during the Economy period. A simple timeswitch may be all that is necessary if a sufficiently large insulated water tank with the correct type of immersion heater is already in use.

Pig and poultry units would show savings on ventilation and, with electricity at 1.94 pence per kilowatt hour being cheaper than any other fuel normally available on the farm, it makes sense to use electricity for heating as well. Mill and mixer units can often be programmed to operate automatically during the night period. Grain dryers operating 24 hours per day would also benefit from the "Economy" tariff, particularly if some heating boost is used during the night period only.

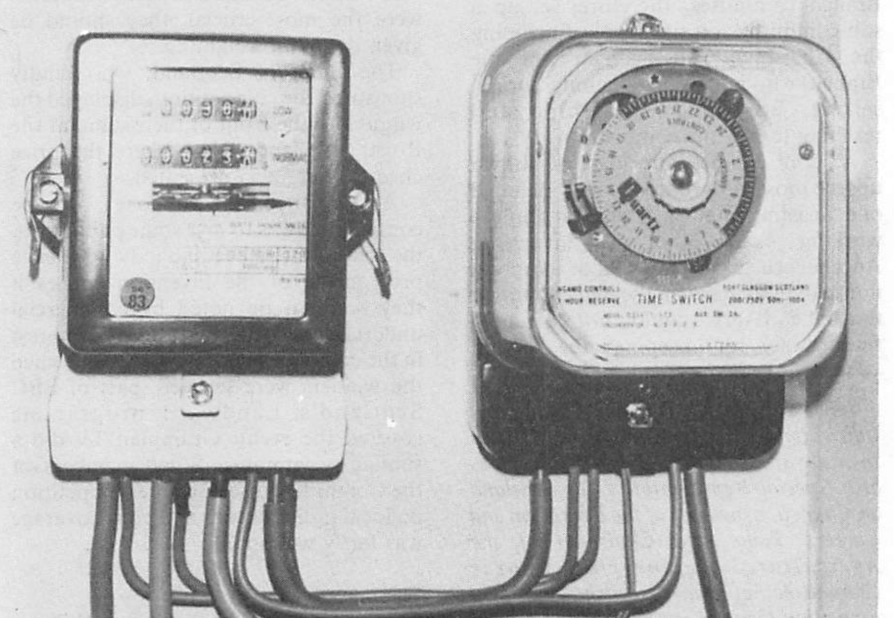
All in all electricity on the "Economy" tariff can be a wise investment and it is well worthwhile asking your local Electricity Board Agricultural Adviser for help.

Table 1 Running costs for potato storage systems (period: 180 days from October to May)

System	*Typical consumption, kWh/t*	*Electricity cost, £/t*	
		Standard tariff	*Economy 90% night use*
Ambient air	22	1.18	0.50
Refrigeration	70	3.78	1.60
Ambient air with refrigeration	54	2.92	1.23

NOTE: The ambient air system was unable to maintain the design temperature of 4°C.

Dual rate meter with time clock



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Scottish Branch Inventions Competition sponsored by the Bank of Scotland

J A Pascal

Introduction

IN 1982, the Royal Society appointed a Committee under Professor Crossland to investigate the British agricultural engineering industry. One of their recommendations was for more effort to be put into bringing private inventions to the attention of manufacturers for possible commercial exploitation.

The Scottish Branch of the Institution, being aware of this recommendation, decided to hold a competition during 1984 for the best farm inventions from Scotland that were not in commercial production (at the time of entry to the competition). It so happened that concurrently with the opening of the competition, the Scottish Farm Machinery Working Group (SFMWG) was initiated by the Scottish Institute of Agricultural Engineering. The remit of this group was to give technical and commercial assistance to private inventors of agricultural machinery and equipment. The Scottish Branch were able to put all entrants with promising equipment in touch with this group which could give them any help required. This in effect became a secondary benefit to competition entrants.

Advice on running a competition of this sort was obtained from a number of organisations and individuals. The greatest assistance was obtained from Ian Duff of N Ireland as the N Irish group of the IAgrE had already run such events and were able to warn us about the difficulties likely to arise and the organisational details required. The Branch committee, therefore, set up a sub-committee of six people (including the Chairman and Secretary of the Branch) who represented manufacturing, selling, advising, researching and teaching to run the competition.

A set of competition rules was drawn up, the most important of which included one insisting that each entrant built a working example of his invention. Another crucial rule was that of accepting non-patented items on the understanding that the IAgrE could not be held responsible for keeping the design confidential. Advice was given on obtaining some form of patent protection but how much protection this provides for the private individual is debatable as any ensuing legal costs to contest an infringement can be crippling. The third important rule made final interpretation of the rules the responsibility of the Branch Chairman. In the event, this last rule had to be invoked on three occasions as personnel of engineering/contract service companies entered inventions and a decision was required on whether the entry was a private or a company one.

It was decided to run the competition for a whole year so that representatives of the sub-committee could see each entry at work during its season of use. A written report (on a pro-forma sheet) was then sent to the sub-committee, who at the end of the year deliberated on these and made up a short leet. All those on this leet were visited subsequently by three or four members of the sub-committee and the final awards made. One difficulty was of course comparing such diverse inventions as an electric fence reel, a rear mounted silage feeder, a lamb resuscitator, an automatic mobile scarecrow, etc. To overcome this variation and make comparisons possible the committee employed three yardsticks, viz:—

1) originality of design — 40% of marks;
2) commercial marketability — 40% of marks;
3) quality of construction of the prototype — 20% of marks.

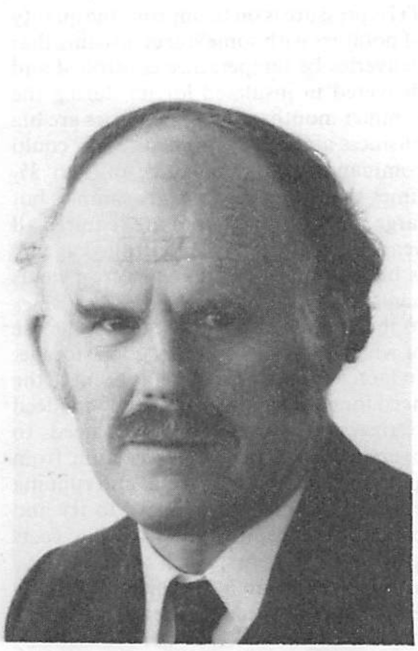
It was felt that as the first two points were the most crucial, they should be given the extra weighting.

The Bank of Scotland, who kindly sponsored the competition, displayed the winners in the front of their stand at the Royal Highland Show where the prize cheques were also presented.

An additional purpose of the competition was to give some publicity to the Institution, since publicity was also a prerequisite of the invention entries if they were to be noted by commercial undertakings. BBC TV expressed interest in the competition at the outset and when the winners were selected, part of BBC Scotland's Landward programme covered the event; Grampian TV did a similar programme. Some members of the Committee discussed the competition on local radio stations and press coverage was fairly widespread.

The inventions

First prize was taken by William



Merriman of Sandwick, Orkney for a rear mounted silage block feeder. The feeder consisted of a vertical frame fitted to the tractor 3-point linkage. A flat plate was attached to the bottom of this frame which was pushed under the silage block as the tractor was reversed up to it. The frame and block were then raised off the ground by the 3-point linkage. At the top of the frame a series of horizontal strakes, fitted with small teeth and attached to hydraulically driven roller chains, combed silage off the top of the block and delivered it to the side. This combing device was allowed to drop on to the block as silage was raked off, the rate of fall and hence silage feed rate, being controlled by an adjustable dump valve on the hydraulic cylinder supporting the combing mechanism. Since the hydraulic motor could be reversed by changing the oil flow direction with the appropriate hand operated valves, silage could be delivered either to the left or the right of the tractor. The machine is now marketed by Messrs. Reekie's of Forfar.

The second prize was awarded to John Caldwell of Arbroath for an automatic bird scarer. The machine basically consisted of a motorised three wheeled bogie on to which the operator could place one or more bird scaring devices eg gas gun, electronic hooter, scarecrow, cartridge banger, etc. Its novelty lay in the fact that the machine could be driven round the field for the first time while unreeling a length of plain wire. Upon returning to the start point of the wire, it was threaded through the steering arm of the single front wheel and the two wire ends joined; thereafter, the machine travelled unattended round the field

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following the wire loop that had been laid. This greatly enhanced the "scarability" of the device compared with stationary bird scarers. The machine is now manufactured and sold by the inventor.

The third prize winner was Sandy Gunn of Halkirk, Caithness for his big bale carrier/forage feeder. In the latter form, the feeder appeared as a conventional mobile cattle feeder for holding hay or silage in a field or court. However, by unfastening a clip at each end of the feeder the sides could be lowered and slid inwards to some extent to provide cantilevered support for the bed as a big bale carrier. The novelty lay in the simplicity of design of the cantilever support system. This item is now manufactured and marketed by Adams Wagons, of Old Deer, Aberdeenshire.

William Hiddleston of Sanquhar, Dumfriesshire, was highly commended for his design of manually operated sheep chair. The dimensions and location of fulcrum on this apparatus were such as to make its use very easy indeed. The inventor manufactures this himself at present to orders received. Two further entrants have their inventions commercially produced, viz:— a rear mounted big bale carrier designed by J D Milne of Inverurie is commercially exploited by Adams Wagons, of Old Deer, and a slurry pump by D Macmillan of Renfrew is commercially exploited by Whitehouse Products of the same location. In addition, a device to enable a tractor driver to maintain bouts at the correct distance apart, is currently being examined for commercial exploitation by an international company.

Conclusions

Some conclusions have been drawn from the competition.

1 The exercise can be said to have been well worthwhile because a number of machines which may not have been commercially produced, have achieved this end. The verb 'may' is used as it is difficult to state in each individual case whether or not commercial exploitation was possible without the competition. However, small firms who took up inventions from the competition obviously welcomed the initial free advertising received by winners through the Press and TV, therefore, we consider that we have assisted significantly in getting some private inventions into production.

2 So far as advertising the Institution is concerned, not one new member has been obtained as a result of the competition. In fact, we may have increased confusion in some people's minds between SIAE and IAgrE. In hindsight, this has been inevitable due to the SFMWG scheme concurrently launched by SIAE and the multiple role of the author as SIAE Liaison Officer, member of SFMWG, Secretary and Organiser of the IAgrE Competition and Secretary of the Scottish Branch, IAgrE (he even got himself confused at times!).

3 The response to the competition was good, even though rather slow at first. Good publicity is essential, as is having a sponsor who is interested in what is being sponsored. The best publicity, so far as getting inventors interested in entering the competition, was the sponsor advertising it in all the Branches of its Bank.

4 We obviously had a back-log of inventions, ie 36 inquiries and 24 final entries were representative of more than one year's output. This raises the question — "Is such a competition viable as an annual event?". The answer must be in the negative and we estimate that a re-run may be worthwhile three to five years hence.

5 The variety of inventions entered was mentioned previously, nevertheless there was a preponderance of machines for feeding or carrying forage in one form or another. In fact, two of the winners were in this category. Does this suggest that the design and operation of current commercial equipment of this type falls far short of expectations? If so, there may be a need for either Universities (such as the Edinburgh School of Agriculture, Silsoe College) or Research Institutes (SIAE, NIAE) to carry out research and development on the subject?

Acknowledgement

The help and assistance of Ian Duff (N Ireland Dept of Agric), David Blight (Director, SIAE) and Neil Bourhill (SIAE) are gratefully acknowledged.

Book Review

Water Engineering

Dennis B Willcock

Publisher: Evans Brothers Ltd, 2A Portman Mansions, Chiltern Street, London W1M 1LE 1983

ISBN 0 237 506831. £2.50

I FOUND this to be a really interesting and useful book. Clearly written with good illustrations and excellent line drawings, which sometimes feature the author's assistant Peter (a matchstick man who illustrates some basic principles which are often difficult to describe in words!), this book is designed to encourage people in schools and polytechnics, particularly in developing countries, to run courses in basic water engineering. This it can't fail to do, providing copies are made available in sufficient numbers in the remote rural areas of the world, where moving water for domestic, industrial or agricultural use is a daily preoccupation.

The book will also be useful in more advanced teaching, where it is important that basic hydraulic principles are understood, and for some farmers.

The book begins with a description of water and then moves straight into a consideration of friction losses in pipes and how to select pipes of the right diameter to provide a given quantity of water. As elsewhere in the book, clear and easy to understand worked examples are used to help the reader to see the relevance in everyday situations.

Lucid descriptions follow of the major types of pumps, pump selection, suction intake arrangements, water flow measurements, well and boreholes. Estimating the power requirements to pump water is illustrated by well chosen worked examples, the reader being introduced to basic mechanics in simple clear ways. Metric units are used throughout with imperial equivalents in brackets *and* italics which minimises confusion.

Chapters on domestic and irrigation water requirements are written in a way that should make it possible for someone with little previous experience to design a practical domestic water supply scheme and a simple sprinkler irrigation system. Surface irrigation though is not covered. A brief description of sewerage disposal, a glossary and a good index follow. Unfortunately though, there is no list of books for further reading.

The author has extensive experience in East Africa working as a water engineer and is also a Member of the Institution of Agricultural Engineers. He is to be congratulated on writing such a useful and unpretentious book for which many a student, teacher and farmer will be grateful, particularly, but not only, those in developing countries. *MKVC*

Grain cleaning and grading: commercial needs and practice — present and future

by J L Marshall

Introduction

These notes are intended to give an overview of the subject of cleaning and grading. Specific detail is not included. The objective is to highlight features of the grain handling process, which may help a producer decide to what extent his crop should be treated.

First, it is useful to consider the "grain cycle". The following diagram is self explanatory, but helps to demonstrate the steps involved in the grain trade.

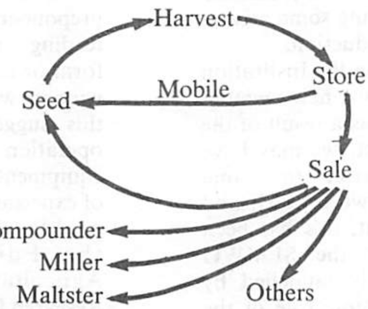

Fig 1 The grain cycle

Cleaning takes place, when necessary, either prior to storage or when the grain is taken out of its "primary store".

Grain cleaning can, therefore, be divided into 2 sections:

1 general cleaning/grading;
2 seed production.

These sections can be further sub-divided into:

1a pre-cleaning;
1b quality improvement;
2a static plant;
2b mobile plant.

Pre-cleaning

Why is there a need to clean into store? With the present surplus situation within the EEC, there is an increasing need to store more grain on farms for longer periods, and therefore greater responsibilities fall on the producers. Grain does not come into store in perfect condition. It always needs to be either cooled or dried and therefore *ventilated.*

The key to successful grain storage lies in adequate and proper ventilation. Only by proper ventilation can one control in-store temperature and moisture, which will then discourage mite and grain pest development.

Admixtures and debris can both impair ventilation and increase the need for it. All admixtures add extra cost to the handling, drying, cooling, transport and storage of the grain. Anything which adds to cost, without any beneficial effect, needs to be avoided. It follows that the most important admixtures which need to be removed prior to storage are those which *impede ventilation* and those which increase the *overall moisture content*, eg unripe grains, green straw, etc.

Joe Marshall is Managing Director of Mobile Seed Cleaning Services, Stibbington, Peterborough.

Quality improvement

This stage includes grading.

Before one can decide on the *degree* of improvement, one has to assess the market potential for the grain, and therefore the potential market requirements.

All buyers are now looking for improved standards of quality. Even the feed compounders would like to see an increase in protein levels, so that they can reduce the amount of expensive imported soya protein. Maltsters, who have always had a quality standard, are now finding their traditional UK markets threatened by imported malt and are insisting on improved quality. UK millers currently use about 4.7 million tonnes of wheat per annum, 75% of which is home produced and they anticipate this to rise to 90% within ten years.

Cleaning and grading of a sample does not improve its biological qualities, but does increase the intrinsic value to the buyer.

Assuming the sample to be acceptable to the buyer in terms of variety, biological and physiological analyses, there are certain physical aspects which need to be satisfied.

1. *Soundness* — This includes freedom from pest damage and pests.
2. *Freedom from sprouting* — This can be controlled by ventilation.
3. *Moisture content* — This is controlled by ventilation.
4. *Margin above minimum specific weight* — This can be increased by up to 5 kg per hectolitre by grading (depending on sample).
5. *Freedom from screenings & admixtures* — This can only be done by cleaning and grading.

At present, we use the time honoured method of aspiration and screening to remove both large and small admixtures and to grade the grain.

In addition to the standard flat bed configuration of screens, some machines use horizontal rotary screen systems and others a vertical rotary centrifugal system. They all require motive power — the vertical centrifugal type being the most demanding.

These systems all work very well, but is there a more efficient, less costly way?

Having identified the potential market, the farmer can now decide on the degree of quality improvement necessary to meet that market requirement. It is no good growing the right variety with the correct N (protein) level, if the physical characteristics prevent it being accepted.

Does the farmer invest in his own equipment or does he employ a contractor?

All farms are different in:
size, layout, location, crop rotation, storage facility and storage requirement.

They are also different in their resources:
manpower, electricity, equipment, buildings and finance.

All these characteristics will influence the farmer's decision.

Seed production

Seed is that part of the harvest which is selected to reproduce to provide the next year's crop. How is it selected?

Apart from specific weight, its physical requirements are similar to those for milling or malting.

Look firstly at the commercial aspects of the seed merchant with static plant.

1. Seed is bought at a premium from the grower. This premium is

designed to compensate the grower for the extra cost of producing a clean, admixture-free sample.

2. Cleaning and grading of this raw material must ensure that, whilst all injurious weed seeds and admixtures are removed, there is minimum degradation of the seed lot in order that:—

3. Maximum sales (as a percentage of the amount bought) is achieved.

In a purpose-built static seed plant, there are no real limitations to size or layout of the various cleaning machines used. For example, there can be a cleaner/grader followed by indented cylinders, followed by separator tables, and all of these units can be totally separate and if necessary, mounted on special bases, without problem.

The main purpose of these units is to ensure that the seed is cleaned to an acceptable standard without removing an excessive weight. This is particularly true for the plant breeder who requires maximum multiplication of new varieties.

The power requirement for this machinery is not critical, as the static plant is serviced by a three-phase mains supply.

Compare those same criteria when applied to a farmer saving his own seed and using a mobile contractor.

1. As there is no raw material to be bought, the only cost is the true cost of production, ie market value LESS profit.
2. High screening percentages are acceptable — indeed desirable.
3. There is no sale.

Although the seed from both static and mobile plant is used for the same purpose, the machinery is very different.

Mobile plant has to be compact — physical size is all important. It has to be efficient in operation. It has to be efficient in power requirement. If farm electric power is used, the largest TP & E outlet socket is 30 amps — otherwise a separate generator must be used.

The design criteria for all cleaner/graders must be:—

throughput, size, durability, ease of cleaning, ease of maintenance, power requirement, capital cost, running cost.

Book Review

Keyguide to Information Sources in Agricultural Engineering

Bryan Morgan

Publisher Mansell Publishing Ltd, London. 1985.
ISBN 0-7201-1720-8. £21.50.

THE books in Mansell's Keyguide series are intended for researchers, librarians and information officers, and the author of this one is well-qualified to deal with his subject, having been Librarian at Silsoe College (formerly the National College of Agricultural Engineering) for many years.

Part I, which is half the book, consists of a necessarily brief survey of agricultural engineering and its literature. The introduction includes a 12-page summary of the history of farm mechanization which with its list of references could be a useful starting point for anyone needing a historical introduction to his own thesis or research paper. The professional and trade organisations serving agricultural engineering in Britain and the US are also mentioned.

The 44 pages on the literature cover journals, theses, reports (including market research and statistics), conference papers, patents, standards and legislation, trade literature, directories and handbooks, and text books. All titles are cross-referenced to the annotated bibliographic listing in Part II. The sections on directories and textbooks are particularly good with a critical approach which would be extremely helpful to anyone setting up a small library. Textbooks and monographs are covered by subject (eg field machinery, mechanization of tropical and developing agricultures, irrigation).

The chapter on searching the literature mentions printed aids such as reviews and abstract journals — there are few in this field — and has a brief section on online databases. It is of course impossible to deal fully with online searching in a book of this scope and I felt that the page or so devoted to the difficulties of searching abstracts, false drops etc, was out-of-place here, since any reader in the information profession will be well aware of them, while the research scientist may be put off the whole idea of using online. The development of online information retrieval, while not the answer to a librarian's every prayer, has brought searches in a variety of diverse subject areas within the means of small libraries. This is valuable for agricultural engineers who must take an interest in many fields of pure science as well as engineering. In the section on databases there is no mention of the patent databases; these present their own problems but are worth getting to know.

A chapter on library classifications for agricultural engineering is not for the non-specialist, but could be extremely useful to anyone setting up a library, or even as a case-study for a student of librarianship! The inclusion of a few pages on sources of films, videos and slides is also valuable.

The annotated bibliography which constitutes Part II gives details of 65 historical books; 70 English-language and foreign journals; 32 directories including lists of machinery manufacturers in a number of European countries, USA, India and Japan; and 244 books with critical descriptions doubtless based on the author's long experience of students' needs. Part III lists 154 organizational sources of information, with names for contact, addresses and descriptions of their activities.

Overall, I feel this is an excellent book for anyone starting off in library or information work in this area. Research staff should find it a helpful introduction to searching the literature, while Part III in particular makes it a handy office or desk reference book. It would be good to know if the publishers plan to update it regularly. The author himself bears witness to the number of excellent reference works which after 20 years must be described as 'out of date but still the best available'. Let's hope that a revised edition of this one will be available around 1990!

EMF

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All main and sub headings should be in lower case typescript except for the first letter of the first word, proper nouns and generic names. The main headings should be typed as a separate line of text with an extra line space above and below and without any underlining. Sub headings should precede the first line of the paragraph to which they relate.

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Underlining should be used only to denote italics for parts of the text and for scientific names of pests, plants, etc.

There should be no stop at the end of any heading or caption unless the last word is an abbreviation of which the stop is a part.
For example:
Yield stability in Vicia faba in the United Kingdom.

5 Title page

The title page should include: the title, and the name(s) of the author(s), their affiliation(s) and passport photograph(s).

6 Summary

The manuscript should include a summary of not more than 400 words.

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The SI system should be used throughout the text as well as in the tables and figures, British Standard PD5686 (1972). The plural of all abbreviations is the same as the singular, eg kg (not kgs). The solidus is used to denote "per" except in the case of more than two units when negative indices are used, eg m/s and $W\ s^{-1}t^{-1}$.

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Smith A B, Jones C D, Frank E F (1982). A mathematical simulation of grain drying. J agric Engng Res, 12, 105–123.

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Cochran W G, Cox G M (1964). Experimental designs. 2nd ed New York, Wiley.

As in the text of the paper, underlining indicates the use of italics.

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