I AGR E

Volume 26
Number 2
Summer 1971

ENGINEERING ASPECTS OF GREEN CROP CONSERVATION

Mechanisation Aspects of Silage Systems
Future Developments in Production and Handling of Hay
Current Work on Conservation Problems
Economic and Management Aspects

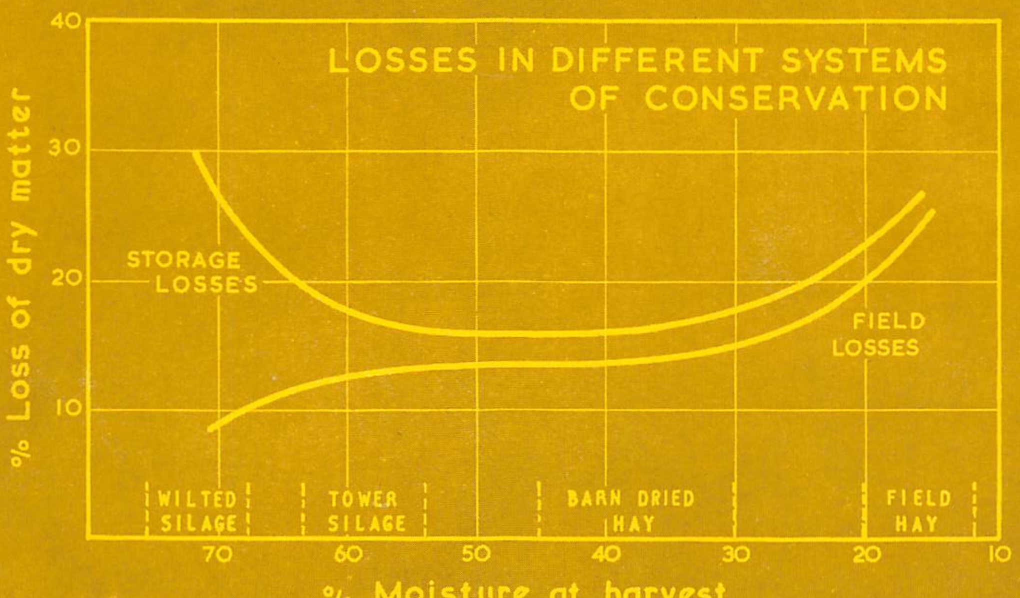
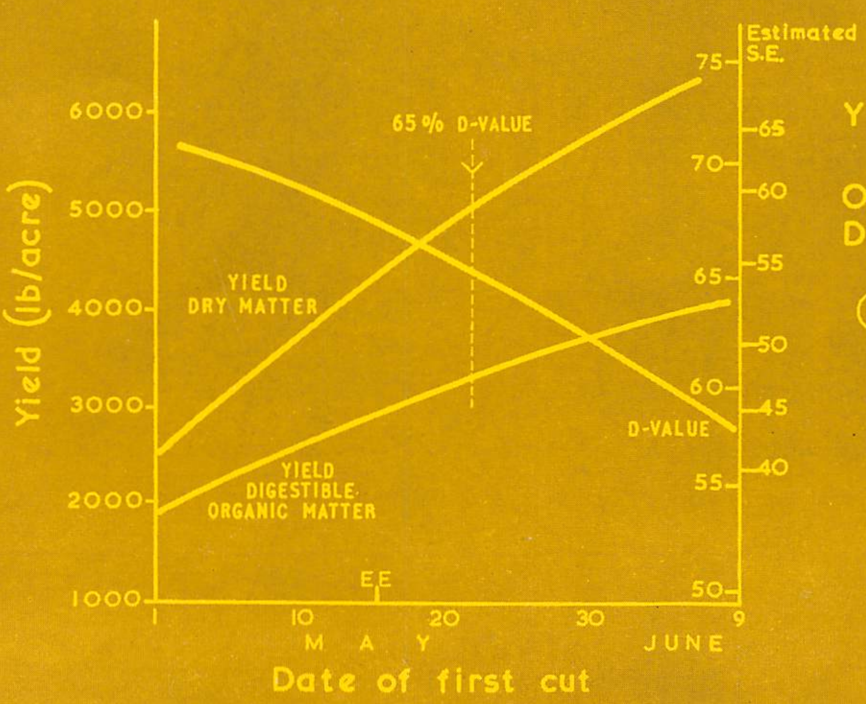
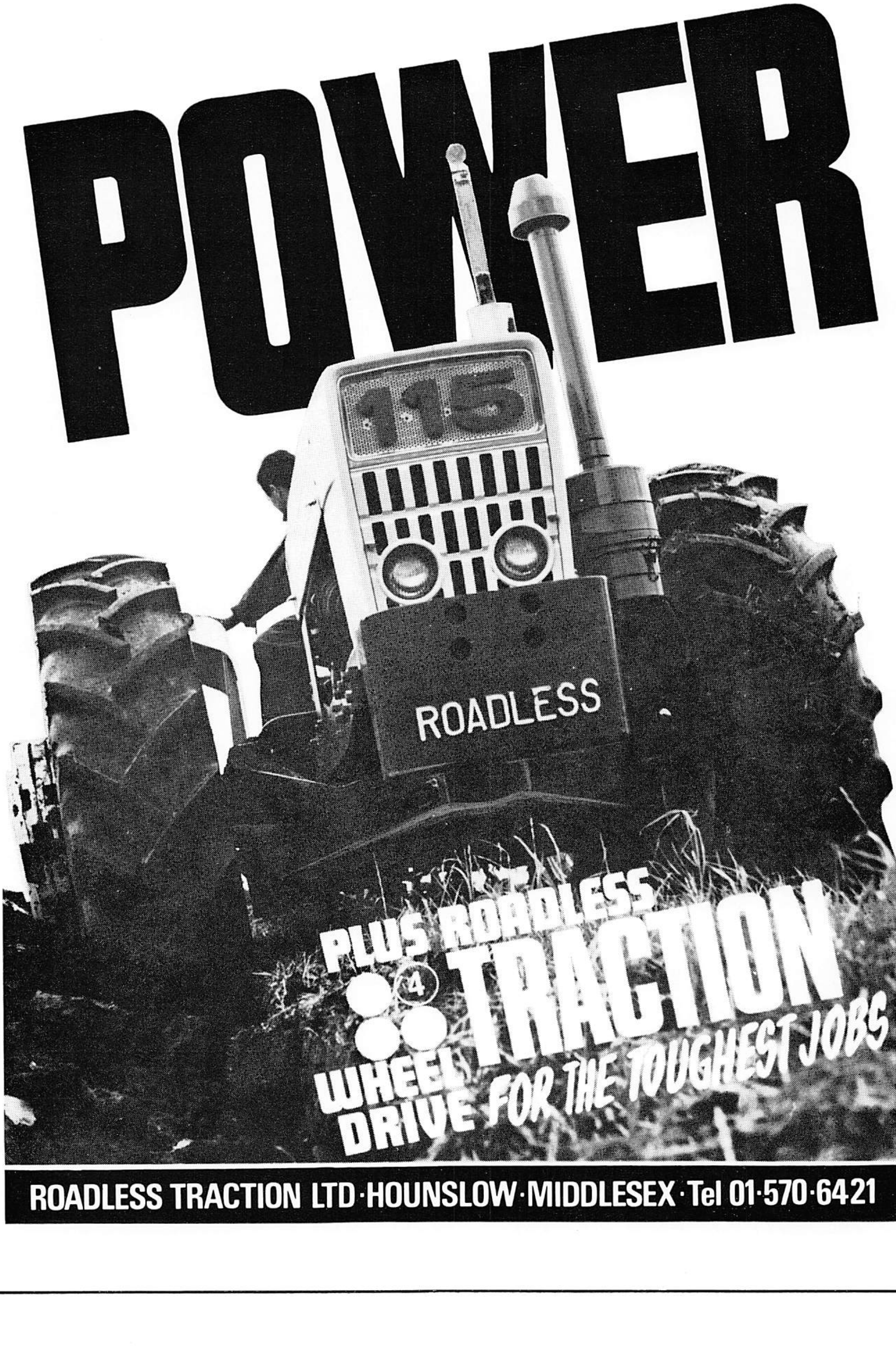


Figure 1



YIELD AND DIGESTIBILITY (D-VALUE) OF S24 PERENNIAL RYEGRASS DURING FIRST GROWTH IN SPRING (100 UNITS FERTILIZER N/ACRE)

Figure 2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GUEST EDITORIAL

Alex Bromfield always wanted to be a master mariner, and with that goal in mind entered the Merchant Navy, as a cadet. He left the sea, however, for family reasons, to become a trainee-executive in the Local Government Service.

At the outbreak of World War II he joined the Royal Navy, to serve as an Officer of the Royal Navy Volunteer Reserve. On demobilisation he sought a fresh career in the field of industrial institutions and associations, occupying a number of executive posts, and making a special study of press and public relations work.

In 1952 he became General Secretary of the Association of Supervising Electrical Engineers (ASEE), out of which grew the Institution of Electrical and Electronics Technician Engineers, founded in 1965. Secretary of IEETE since then, he is currently acting as Chairman of the Technician Engineer Section Board of the Engineers Registration Board (ERB), and Chairman of the CEI cross-disciplinary panel for technician engineering qualifications.

Author of numerous papers and articles, he is Managing Editor of IEETE publications.

THE WIDENING SCENE

by E. A. BROMFIELD

With last month's first formal meeting of the ERB Technician Engineer Section Board, engineering reached a milestone of marked significance. Soon the nucleus of the Technician Section will be formed, and the completion date for the Composite Register well in sight.

Achievement so far is really quite remarkable, when one considers all that has taken place since CEI first brought 40 organisations together in December 1967 for informal talks. Often the four-year forum has been a battlefield, but the firing nowadays is at longer range and more desultory; the thicker smoke is clearing and the common target can be seen more clearly. Many believe that all that has happened has been for the best, and that everything is 'coming out in the wash'. But why look back at all, when there is a great deal to be done today, and so much more tomorrow?

If we peer at the outer range rings of our radar, what can we see? We can discern (over the next twelve months, if not sooner) the protected designatory letters for technician engineers and technicians becoming as well grouted-in as are those for chartered engineers. We can foresee further improvement in technician engineer status; a wide recognition of the ERB's authority and sincerity of intent; a greater understanding between all concerned. We can also see the sections of the Registration Board becoming a bureau for many matters affecting the collective interests of the Engineering Community.

Although the CEI Charter By-laws do not provide ERB with formal authority for this, is it not understandable (and desirable, too) that people of so many disciplines who have worked and warred together for so long should now wish to extend that work in a positive and more cohesive way? After all is said and done, what other means will they have, (now that SCNQT is deceased, and the Engineers' Forum has foundered) of getting into a huddle whenever they want to?

So, let us look at just a few of the possibilities for such wider cross-disciplinary consultation. First, technical education. The qualifications committees of the ERB sections could, together, be a 'natural' for DES and other educational authorities in their sounding-out exercises. Then, take training. The ERB sections will surely wish to keep in close touch with current thinking among the many training boards working within the Engineers Registration Board catchment areas; for acceptable standards of training are important components in the eligibility make-up of personnel admitted to the Composite Register. Again, management manpower is a major problem for engineering, and it is to the technician engineer echelon that the boardroom is beginning to turn, more and more, for recruitment to and replacement of this indispensible force.

Another example is the Common Market, and the distinct possibility of Britain entering the EEC. Already much work is being done by UNESCO and others towards the harmonisation of engineering and other qualifications. If we do go into Europe, then alignment of our technician engineering standards and designations with those of European countries will be a must: acceptance of our recognition signals, *TEng(CEI)* and *Tech(CEI)*, within a truly international comprehensive register of qualified personnel will become imperative. It may well be that the Government have this in mind, because Mr John Davies, Secretary of State for Trade and Industry, said last February, when answering Parliamentary questions about the ERB: "This development is an important step in establishing standards of engineers at all levels, and in providing a basis for registration to practise should this be necessary for employment abroad."

So, why should the three ERB sections not get together for common studies of all such matters? The work could be carried out quite informally, and without commitment.

To end, an opportune word about Jon Bennett, now leaving his pastoral pursuits with the Agriculturals to work in plant engineering as Secretary of I Plant E. Jon, who has contributed a great deal towards the registration endeavours, is Chairman of the ERB Technician Engineer Section Board Admissions Committee. It is a job that calls for unassailable integrity and sound knowledge of what is involved, and he is fulfilling it with consummate skill. □

INSTITUTION NOTES

The New President

Claude Culpin, OBE, MA, Dip Agric (Cantab), FI Agr E, was elected President of the Institution at the Annual General Meeting in May. He succeeds George Henniker-Wright who retains Council office as Immediate Past President.

Claude Culpin joined the Institution in 1946 and first became a member of Council in 1951. From 1965 to 1968 he was a Vice-President and in 1969 he was appointed President-Elect. He has been Chairman of the Finance and General Purposes Committee as well as being active on a number of other Institutional Standing Committees and Working Parties. He has lectured widely at Institution National Conferences and Branch meetings. For more than twenty years he has served as the Assessor representing the Ministry of Agriculture, Fisheries and Food on the Examination Board in Agricultural Engineering.

A keen supporter of CIGR (the International Commission of Agricultural Engineering), Claude Culpin is the Institution-appointed UK representative on the Management Committee. He has been closely concerned with CIGR activities since 1951 and has travelled extensively in Europe in the furtherance of its objectives.

In his school years, Claude Culpin lived on a progressive East Anglian farm, and this home background influenced him towards a degree in natural sciences when he went to Cambridge, where he went on to acquire the University's post-graduate diploma in crop husbandry. He then spent short periods with agricultural machinery manufacturers and a year at the University Department of Engineering, studying subjects considered appropriate to his future work (1933-40) as lecturer in agricultural engineering in the University Department of Agriculture.

During 1940-45 he was County Agricultural Organizer in Worcestershire. He then became Agricultural Engineer and later Agricultural Manager in the Nuffield Organization, during which time the first Nuffield tractor was developed and tested; but post-war manufacturing problems held up production for a time, and Mr Culpin moved on to the then infant National Agricultural Advisory Service. He was soon appointed Chief Mechanization Adviser, and occupies a similar post in today's ADAS. He has travelled abroad extensively on fact-finding missions, and particularly on international standardization of agricultural machinery.

Claude Culpin's book *Farm Machinery*, now in its eighth edition, has for long been at the top of the list of required reading for students of agricultural engineering and farm mechanization. His second book, *Profitable Farm Mechanization*, deals mainly with economic aspects of mechanization.

Highlights of the AGM

Hard on the heels of the Presidential election at the Annual General Meeting in London on 6 May, came the announcement that Mr J. A. C. ("Ian") Gibb had been elected the Institution's President-Elect. Ian Gibb, a Fellow of the Institution, is Senior Lecturer in Agricultural Engineering at the University of Reading. He has been a Vice-President of the Institution for the past two years and has for a long time played a ubiquitous role in the Institution's development. He is perhaps best known to the membership at large for his work as Honorary Editor of the *Journal* and other Institutional publications. He is also Chairman of the Examination Board in Agricultural Engineering and serves also on many Standing Committees and Working Parties.

Another Fellow, Peter G. Finn-Kelcey, becomes a Vice-President for the first time, although he is no new-comer to the Council and, moreover, he has long been an active worker in the Institution's Western Branch. By profession he is an agricultural engineering consultant with strong electrical leanings. Other Fellows who have been elected to the Institution Council for 1971-72 are Mr H. F. Howell (Massey-Ferguson), Mr R. H. Miers (ADAS) and Mr J. C. Turner (Rycotewood College). Two Members who have joined the Council are Mr L. P. Evans (Massey-Ferguson) and Mr J. A. Howard (Howard Rotavator Co). Mr R. H. Mander, an Associate with a background of farming and farm buildings, also makes his debut on the Council.

It was learned with great regret at the AGM that a distinguished Fellow and Past President of the Institution, Mr F. E. Rowland, had felt that the time had come to bring his long period of unbroken service on the Council to a close. The meeting put on record a Vote of Thanks, carried with acclamation, in tribute to Frank Rowland's outstanding and uniquely personal contribution to the Institution's development and general well-being, especially during its formative years.

The Annual Report of the Council for 1970 was presented by the outgoing President, George Henniker-Wright. He pointed out that this was his Presidential swan song and his remarks would therefore be bound to strike a reminiscent note concerning his two years in office.

With regard to the CEI situation, Mr Henniker-Wright said it must be clear from the substantial coverage given to it in the Council Report that the Institution had come a long way. On becoming President in 1969 he had been alarmed at the extent to which engineering registration had torn and divided opinion in the profession, presenting a tangled maze of hopes and fears, the outcome of which nobody at that time dared predict. CEI itself had done much since then to bring order out of chaos and this deserved full acknowledgment. This Institution, together with a few other bodies, chartered and non-chartered, had been right out in front, helping to get the new Engineers Registration Board into being. Success on this front was now only a matter of a few weeks away.

"These developments are of great significance to the agricultural engineering community", said Mr Henniker-Wright. "Our industry is under great pressure these days. Amid all the present industrial uncertainty and swirling unrest, we want to see stabilizing forces at work to hearten us all and inspire our confidence. The composite registration scheme for the engineering profession places proper emphasis on high standards of education, training and industrial experience. Since 1965, we have had the Chartered Engineers register and now we are about to have this register extended to include new sections for technician engineers and technicians. These are the kind of people who form the backbone of our Institution—indeed, of our industry—and what better can we do than reach out and give them a real sense of identity and a goal of career-based achievement?"

Mr Henniker-Wright went on to assure the meeting that within a fairly short time, the Institution expected to be an Inaugural Member of the Engineers Registration Board and one could make a start in getting some hundreds of the Institution's members registered. He stressed that registration in the new sections of the register would be voluntary. It would only work and really mean something if everybody wanted it to do so. The Institution would have played its part; soon it would be up to members to play theirs by applying to be registered and encouraging others to first join the Institution in the appropriate membership grade and then to register. This, said Mr Henniker-Wright, was how to get agricultural engineering on the map as an influential professional force in this country.

Mr Henniker-Wright next turned to the subject of membership recruitment. "I have some strong views on that subject", he said. "Membership is nothing like as high in numbers as it should be. You know it and I know it. I have no complaint about the quality. The good standing we enjoy in CEI and elsewhere suggests there is not much wrong there. And I am pleased to see our Graduate and Student grades building up well. But let us face it—our corporate membership is not moving up very much at all and nobody can convince me that our Institution is anywhere near its ceiling yet."

There were two reasons, Mr Henniker-Wright went on, why he wanted to see the membership numerically higher. One was that the Institution ought to be representing the entirety of qualified engineering manpower in agriculture, and not just a part of it.

The second reason was more mundane but just as important. A higher rate of growth was necessary to bring in the income necessary to meet the Institution's rising operating costs. Some really effective recruitment should be taking place in the coming months, spurred on by the availability of the new Technician Associate grade, plus the prospect that both Members and Technician Associates would be able to draw forefront benefit from the new registration scheme.

Registration on the one hand and membership growth on the other were closely linked, Mr Henniker-Wright continued. The whole future of the Institution might well depend upon being successful with both. "Let us make that effort", he challenged. "Your Council is pledged meanwhile to press on with finding solutions to our remaining problems such as affiliation to CEI and, along with it, access to the chartered engineers section of the register. We are not at the end of that road yet but we see some encouraging signposts and scenery as we travel along it."

Mr Henniker-Wright went on to deal briefly with the remainder of the Council Report. He wanted, he said, to highlight the immense amount of work put in by members behind the scenes, whether on Standing Committees, Working Parties, Branch Committees, the Examination Board or whatever it might be. Events like the Annual Conference or a Branch Conference took months of planning and preparation by members who gave up their time with no thought of reward other than to make a success of their ventures.

Mr Henniker-Wright concluded by thanking the Secretary, Jon Bennett, and his staff for their tireless and loyal assistance and wished his own successor, Claude Culpin, a happy and successful Presidential term.

At the conclusion of the Annual General Meeting, amid general acclamation, Mr Henniker-Wright introduced Mr Culpin and formally vested him with the Presidential Badge of Office.

A Secretary Goes Home from Home

Jon Bennett to leave I Agr E for I Plant E

The Council very much regrets to announce that the Institution is shortly to lose the services of its chief executive, Jon Bennett. After nearly eight years as this Institution's Secretary, he is to take up appointment in October as Secretary to The Institution of Plant Engineers.

So similar in outlook are the two Institutions on a variety of subjects affecting the wider engineering community that Jon Bennett himself has been heard to say that it will be rather like 'going home from home'. He also freely admits that leaving his present job will be a tremendous wrench.

In a recent exchange of Presidential letters, Claude Culpin said to his opposite number, John Lang of I Plant E, that while the Agriculturals would be sorry to lose Jon Bennett, the Council was pleased that he was going to the Plants and hoped that it would lead to further development of the friendly and productive contacts that had built up between the two Institutions. John Lang replied in a tone which warmly reciprocated and endorsed those views.

The I Agr E Council, at its July meeting, unanimously agreed to express formal appreciation of the outstanding service which Jon Bennett has given to this Institution. Particular mention is to be recorded of his contributions in respect of efficient organization and office management, and in the steps taken towards national registration of agricultural engineers via the Engineers Registration Board and the Council of Engineering Institutions.

□

OBITUARY

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

Howard, A. C.	*Fellow*
Watson, P. S.	*Member*
Wilson, J.	*Fellow*

Reprint Service

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

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Institution Activities

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

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Asst. Secretary (Publicity):
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The Institution of Agricultural Engineers
Penn Place, Rickmansworth, Herts.

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

EAST MIDLANDS
Branch Hon. Secretary:
R. D. S. BARBER, BSc, ND Agr E, MI Agr E
Kesteven Agricultural College, Caythorpe,
Nr. Grantham, Lincs.

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

NORTH WESTERN
Branch Hon. Secretary:
F. J. HEATHCOTE, AI Agr E
Longmede, Church Fold, Off Chapel Lane, Coppull,
Nr Chorley, Lancs.

SCOTTISH
Acting Branch Hon. Secretary:
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Donmaree, Springhill Road, Peebles

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Branch Hon. Secretary:
K. A. McLEAN, NDA, CDA, CDAE, ND Agr E,
MI Agr E, Min of AFF
Beeches Road, Chelmsford, Essex

SOUTH EAST MIDLANDS
Branch Hon. Secretary:
G. SPOOR, BSc (Agric), MSc (Agr Eng), MI Agr E
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Engineering Department,
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Branch Hon. Secretary:
J. MAUGHAN, BSc, MSc, MI Agr E
48 The Hollows, Bessacarr
Doncaster, Yorks.

C

NEWSDESK

Engineers Registration Board

The Technician Engineer Section of the Engineers Registration Board was formally inaugurated in July. The Inaugural Ceremony took place at the London Headquarters of the Council of Engineering Institutions (CEI), the occasion being chaired by Sir Eric Mensforth, CEI's Chairman. The event was distinguished by the presence of Sir Godfrey Agnew, Clerk to the Privy Council, who warmly congratulated all concerned in the difficult task of helping to establish the long-awaited composite register to cater for substantially the whole of the engineering profession. Others at the Ceremony (see photograph on opposite page) included CEI senior officers and representatives of the various institutions who have been actively concerned with registration.

On 12 August the Technician Engineer Section Board held its first meeting. The following corporate bodies were affirmed in Membership of the Section.

The Institution of Agricultural Engineers
The Institution of Heating and Ventilating Engineers
The Institute of Works and Highways Superintendents
The Institution of Electrical and Electronics Technician Engineers
The Institution of Electronic and Radio Engineers
The Institution of Engineering Inspection
The Institution of Engineers and Shipbuilders in Scotland
The Institution of Gas Engineers
The Institution of Mining Engineers
The Institution of Plant Engineers
The Institution of Production Engineers
The North East Coast Institution of Engineers and Shipbuilders
The Royal Aeronautical Society
The Royal Institution of Naval Architects

Applications from other corporate bodies are now being treated in accordance with the By-Laws and the Technician Engineer Section Board has set up procedure for examining further applications. Several Committees, notably for Admissions, Qualifications, Registration and Finance were formed, in embryo, so that there is the opportunity for participation by further applicants admitted to membership of the Section Board within the next few months. It was agreed that there should, at this stage, be no permanent appointment of officers and Mr E. A. Bromfield (The Institution of Electrical and Electronics Technician Engineers) was appointed to act as Chairman until the end of the year when the Section will elect its first Chairman under the Regulations. Mr Jon K. Bennett (The Institution of Agricultural Engineers) was appointed Chairman of the Admissions Committee.

Whilst the progress in registering individuals will depend on the sponsoring bodies the Section Board expects nominations to the Register to commence in October 1971, with the designatory letters *T Eng* (*CEI*) coming into use at that time.

It is planned that the *Technician* section of the ERB will be inaugurated shortly and informal talks to this end are continuing.

More about Metric

The Metrication Board had a display on the Ministry of Agriculture Stand at the Royal Ulster Agricultural Show in Belfast last May. Its aim was to show farmers and growers how industry's change to metric would affect them. This was the first display of its kind.

Farmers already use metric units for some purposes, says the Board. Metric supplies such as pharmaceuticals are already common. Metric building materials and components are becoming more widely used. As the changes in industry progress, products and materials used in farming will be increasingly marketed in metric.

The display at the Ulster Show was one of a series of Metrication Board exhibits aimed at specialized sectors of industry. A further display was given at the Royal Show.

A two-day conference on electrical and mechanical engineering is planned by the Board to take place in the Autumn. Speakers will describe their experiences in planning and carrying out the metric change in the industries they represent. This will give an authoritative and up-to-date picture of the progress of metrication in each sector. The conference is expected to be of particular use to those who cater for the needs of medium-sized and smaller firms. For further details of programme and speakers, enquiries should be addressed to the Metrication Board, 22 Kingsway, London WC2B 6LE.

Who Chooses the Cab for the Tractor?

Tractors can have any approved cab of the owner's choice. This is the conclusion that can be drawn from a Ministry statement in the House of Commons, in answer to a Parliamentary question.

According to the statement, the Government's objective has been to enable those who buy new tractors to have them fitted with approved cabs of their own choice. Consultations with all the interests concerned showed that the amendment originally proposed for the regulations on safety cabs would not in itself necessarily secure this objective, and that the safety problems inherent in allowing new tractors to be sold without cabs could not be overcome.

The safety standard of each type of cab is tested officially before it is approved for use with a particular tractor. The Government propose that in future the scope of the assessment should be extended to include the *technical* suitability of the particular cab for use with the particular tractor, including any exceptional level of noise levels, and for this purpose the agricultural departments will have regard to the tractor manufacturers' views.

Interests concerned are being consulted on this proposed statutory change, which should remove any occasion for discarding a cab on the grounds that it limits normal use of the tractor concerned.

Under amended regulations, it will still be necessary for new tractors to be fitted with a cab at or before the point of sale. In the meantime, all the leading tractor manufacturers have assured the Government that, in order to ensure continuing compliance with the law, they will introduce arrangements under which the customer will be able to obtain any of their tractors fitted with any approved cab of his choice, and with an appropriate discount for omission of their cab or frame.

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Those present at the July Inaugural Ceremony of the Engineers Registration Board in London were (from left to right) T. J. Coppin (not fully in view), (Institution of Electronic and Radio Engineers); R. D. Turner; A. M. Ballantyne (Royal Aeronautical Society); A. G. Higgins (Institution of Gas Engineers); E. A. Bromfield (Institution of Electrical and Electronics Technician Engineers); A. G. Stone (Institution of Plant Engineers); J. K. Bennett (Institution of Agricultural Engineers); Miss R. Winslade (CEI); M. W. Leonard (CEI); Sir Eric Mensforth (Chairman of CEI); Sir Godfrey Agnew (Clerk to the Privy Council); W. Woodford (Institution of Production Engineers); R. Miskin and D. Squirrell (Institution of Engineering Inspection); P. Ayling and M. McCallum (Royal Institution of Naval Architects); B. A. Hodges and F. Martin (Institution of Heating and Ventilating Engineers).

Renumbering of City and Guilds Examination Schemes

For some time City and Guilds of London Institute has experienced increasing difficulty with its present system of numbering examination schemes. This has arisen largely because of the extensive introduction of new course structures over recent years. The present numbering system was introduced some 30 years ago and the Institute now considers a revised system to be necessary.

The complete renumbered list is too long to reproduce here but the following are the courses, showing the old and new numbers, which are likely to be of particular interest to the agricultural engineering community, and especially to school-leavers who are about to embark on an agricultural engineering career.

New No.	Title	Old No.
015	Agricultural Mechanics	*260
029	Agricultural Engineering Technicians (Old Scheme)	261
030	Agricultural Engineering Technicians (New Scheme)	465
255	Mechanical Engineering Technicians	293
811	Agricultural Engineering in Tropical Countries	816-8

*The examinations under 260 in Livestock Feeding and Slurry Handling Equipment and Root Crop Mechanization and Storage Equipment were held for the last time in May/June 1971. Examinations in other extension subjects will continue.

A Broadsheet suitable for display on notice boards and giving the complete list of renumbered City and Guilds courses are obtainable free of charge from the CGLI Publications Officer, 76 Portland Place, London W1N 4AA.

Queen's Award to Industry

For the third time since its inception in 1966, a Queen's Award to Industry has been conferred on David Brown Tractors Ltd. The company was previously honoured in 1966 and 1968.
In the face of a world recession in sales, afflicting all tractor manufacturers alike, the award hall-marks David Brown's success as an exporting organization and should give heart to the whole agricultural engineering community.

No apology to competitors for this bit of free and unsolicited publicity for David Brown. The news, amid the industrial gloom, that a major tractor manufacturer has wrought a Queen's Award Hat Trick should surely cheer up every agricultural engineer in the land. And it is the established editorial policy of this *Journal* to keep its readers happy.

FORTHCOMING EVENTS

Institution Activities

SEPTEMBER 1971

TUES. 14—10.15 to 16.00—EAST ANGLIAN BRANCH (in conjunction with the FARM BUILDINGS ASSOCIATION)
Conference on Slurry Handling Techniques.
Speakers: C. T. Riley, K. C. B. Jones and D. E. Willows of ADAS. Chairman: J. D. Alston, JP. To be held at East Suffolk Agricultural Institute, Otley, Ipswich.

MON. 27 at 19.30—WEST MIDLANDS BRANCH
Hydrostatic Drives in Agriculture by J. Matthews and W. P. Billington of NIAE. To be held at the Massey-Ferguson Training Centre, Stareton, near Kenilworth, Warwicks.

THURS. 30—10.15 to 16.30—AUTUMN NATIONAL MEETING
Conference on Engineering for Milk Production.
Ticket admission only. For full programme details see page opposite. To be held in the Theatre of the Faculty of Letters Building, University of Reading, Reading, Berks.

THURS. 30 at 11.00—EAST MIDLANDS BRANCH
Visit to Marshall-Fowler Ltd, Hunslet, Leeds. Works tour followed at 14.30 by lecture, *Crawler Tractors in Agriculture* by H. F. W. Flatters.

OCTOBER 1971

MON. 4 at 19.30—SOUTH EAST MIDLANDS BRANCH
Developments in Welding Techniques by T. Martin of the Welding Institute, Cambridge. To be held at NCAE, Silsoe, Bedford.

MON. 4 at 19.30—WREKIN SUB-BRANCH
EEC—What is the Future of the British Agricultural Engineering Industry? by A. M. Littlejohn of the Agricultural Engineers Association Ltd. To be held at Sanders Hall, Staffs College of Agriculture, Rodbaston, Penkridge, Staffs.

THURS. 7 at 19.30—SOUTH EASTERN BRANCH
The Utilization of Tractor Power by J. B. Finney of ADAS. To be held at Essex Institute of Agriculture, Writtle, near Chelmsford.

THURS. 7 at 19.30—YORKSHIRE BRANCH
New Methods of Grain Conservation by D. J. Greig of the University of Newcastle upon Tyne. To be held at Askham Bryan College of Agriculture and Horticulture, Askham Bryan, York.

TUES. 12 at 19.30—EAST MIDLANDS BRANCH
Water by F. Marshall of Trent River Authority. To be held at Notts College of Agriculture, Brackenhurst, Southwell, Notts.

TUES. 12 at 19.00—NORTHERN BRANCH
Electricity: A Factor of Farm Production by P. Wakeford of the Electricity Council. To be held at the Agricultural Department, University of Newcastle upon Tyne.

THURS. 14 at 19.30—SOUTH WESTERN BRANCH
Manure Handling Systems by G. F. Shattock of ADAS. To be held at the Duchy Restaurant, The Parade, Liskeard.

MON. 18 at 19.00—WREKIN SUB-BRANCH
Design and Development of Tyres in Agriculture by a speaker from Goodyear Tyre & Rubber Co Ltd followed by a factory tour. To be held at Goodyear Tyre & Rubber Co Ltd, Stafford Road, Wolverhampton.

TUES. 19 at 19.30—SCOTTISH BRANCH
Potato Storage and Handling by O. Statham of the Potato Marketing Board. To be held at the Royal Hotel, Forfar.

WED. 20 at 19.45—WESTERN BRANCH
Soils and Machines by Dr H. N. Pizer of MAFF. To be held at Royal Agricultural College, Cirencester.

MON. 25 at 19.30—WEST MIDLANDS BRANCH
Is Agricultural Engineering Education and Training Right for Today's Requirements? A Forum with speakers: A. Webb of AHFITB, D. Belton of RTITB, A. Lacey of EITB, D. Griffiths of Midland Shires Farmers Ltd, B. Banting of Salford Priors and D. Hunt of Massey-Ferguson Ltd. To be held at the Electro-Agricultural Centre, Stoneleigh, Warwicks.

THURS. 28 at 19.30—NORTH WESTERN BRANCH
The Application and Effect of Power on the Land by J. B. Finney of ADAS. To be held at Lancs College of Agriculture, Myerscough Hall, Billsborrow, near Preston.

Other Activities

OCTOBER 1971

THURS. 30 (Sept) to SAT. 2—18th WORLD PLOUGHING CONTEST
To be held at Nynehead, Wellington, Som.

WED. 6 to FRI. 8—AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
Irrigation and Drainage Specialty Conference co-sponsored by ASCE and ASAE. To be held at Lincoln, Nabraska, USA. Enquiries to ASCE, 345 E. 47th Street, New York, NY 10017, USA.

TUES. 12 to THURS. 14—ROYAL ULSTER AUTUMN SHOW AND SALE
To be held at Balmoral, Belfast, Northern Ireland.

THURS. 21—SUGAR BEET NATIONAL AUTUMN DEMONSTRATION
To be held at Witham, Essex.

MON. 25 to FRI. 29—AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
Seventh American Water Resources Conference. To be held at Statler Hilton Hotel, Washington DC, USA. Enquiries to J. D. Wray, N. Carolina Dept of Air Resources, PO Box 27048, Raleigh, NC 27611, USA.

WED. 27 and THURS. 28—NATIONAL AGRICULTURAL CENTRE COURSE
Dairy Husbandry. To be held at NAC, Stoneleigh, Warwicks.

THURS. 28 and FRI. 29—AGRICULTURAL MACHINERY & TRACTOR DEALERS ASSOCIATION LTD
Effective Management. AMTDA Joint Convention at the De Montfort Hotel, Kenilworth, Warwicks. Enquiries to AMTDA, Penn Place, Rickmansworth, Herts. □

THE INSTITUTION OF AGRICULTURAL ENGINEERS

AUTUMN NATIONAL MEETING 1971

To be held in the
Theatre of the Faculty of Letters Building,
University of Reading,
Whiteknights Park,
READING, BERKSHIRE
THURSDAY, 30 SEPTEMBER 1971

ENGINEERING FOR MILK PRODUCTION

Programme Convener: F. L. GAMMON, Regional Mechanization Adviser, Agricultural Development and Advisory Service (ADAS)

PROGRAMME:

10.15 Reception and Coffee

10.45 Introduction by C. CULPIN, President of the Institution and Chairman of the First Session

10.50 Paper 1
Manure Disposal from the Dairy Herd by G. F. SHATTOCK, ADAS Mechanization Dept., Reading

11.15 Discussion of Paper 1

11.30 Paper 2
Housing and Building Design for Dairy Herds by C. DOBSON, FBAO, ADAS, Reading

12.10 Discussion of Paper 2

12.30 Luncheon Interval

13.45 Meeting Resumes—J. A. C. GIBB, President-Elect of the Institution and Chairman of Second Session

13.50 Paper 3
Feeding Dairy Cows by J. I. PAYNE, National Livestock Mechanization Specialist, ADAS

14.15 Discussion of Paper 3

14.30 Paper 4
Milking Systems and Equipment by P. CLOUGH, National Institute for Research in Dairying

14.50 Discussion of Paper 4

15.10 Paper 5
Future Developments, Automation and Automatic Controls by E. J. CANT, National Institute for Research in Dairying

15.30 Discussion on Paper 5

15.45 **Open Forum:** Introduction by N. FAIREY, Manor Farm, West Tisted

16.30 Tea and Dispersal

TICKETS

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

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

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

NEWS FROM BRANCHES

A New Branch in Essex

The Institution Council recently gave its approval to a new Branch of the Institution being formed comprising members resident in the county of Essex. It will be known as the South Eastern Branch and, following on the heels of the recently formed North Western Branch (reported in the Spring 1971 issue of the *Journal*) it brings the total number of Branches in the Institution's UK network to eleven.

This heartening development comes as the result of some hard work in recent months by the Essex/Kent Group under the Chairmanship of Mr E. N. Griffith, CBE, CI Agr E. The Group was established in October 1970 for the purpose of sounding out support from the membership in the area for a possible Branch. Two exploratory meetings have been held, attracting more than sixty members and visitors on each occasion. The first took place at Essex Institute of Agriculture on 13 January, the subject being 'The Autotrack System of Driverless Tractor Control'. The second meeting was held at Rotary Hoes Ltd, East Horndon, the topic on that occasion being 'Some Aspects of Heavy Land Cultivation'. Both meetings were widely publicized, notices being sent to all members in the area, the agricultural engineering trade and selected farmers in Essex and Kent.

It is pleasing to note that both the exploratory meetings attracted a goodly number of students from Essex Institute of Agriculture. Their attendance is considered important, especially those studying for the ND Agr E, because they must be regarded as potential members. The Hon Secretary of the Group, Mr K. A. McLean, reports that the interest of visitors in membership has been good, several membership application forms having been completed and returned.

Possibly the relatively scattered nature of the Kent membership accounts for the fact that not many of them have featured in audiences at the exploratory meetings. One conclusion is that the division of Kent from Essex by the Thames renders it more practicable for those members to support London-based activities. The hope remains that Institutional development in Kent will come about through a natural process of growth and the Committee of the new Branch has been asked to keep in loose touch with Kent members, with this in view.

All in all, 1971 looks like turning out to be a good year for the Institution's healthy regional development. The Committee of the former Essex/Kent Group—now the Inaugural Committee of the South Eastern Branch—are understandably in high spirits at the way things have gone and rightly feel that the new formation will contribute to the strength of the existing Branch network. They are now busy planning their first full programme of lectures, visits and social events for the winter session 1971-72.

A Presidential Crusade

With only a few weeks to go before the end of his term of office as the Institution's President, George Henniker-Wright made some stirring and challenging utterances during the Spring Tour of the Branches.

Institutional growth was the theme of his forthright sermon. "Let me be quite blunt about it", he said. "If our Institution expects to stay in business, it has got to get its numbers up". He pointed out that over the past year or two, membership growth had been at an annual nett rate of only around 2 per cent. Part of the struggle to maintain agricultural engineering as a living, industrial force must be to ensure that this Institution was a strong, pace-setting body. To be this it had to be as strong in numbers as it already assuredly was in quality. The quality was of the kind that industry needed and ought to want.

"It amounts to this", said the President. "We need a higher rate of growth to keep pace with the cost of quality. The one goes with the other these days. There is a recruitment campaign on and you are all in it. We would like every member to go out of his way to introduce at least one new potential member to the Institution in 1971. If everybody in the Institution did this, our membership would exceed 4,000 within twelve months. There is nothing impossible about this and it could actually happen if every member was determined enough".

Referring to the Institution's role in the new CEI registration scheme, Mr Henniker-Wright said that in his opinion this was something every member should be proud of. Agricultural engineers in the Institution's grade of Member would be among the very first to benefit from it. The point to remember was that to get himself registered with the designation *T Eng (CEI)*, a man had first to join a qualifying institution which was itself a member of the Engineers Registration Board. In agricultural engineering, this Institution was the one. When a man became an *MI Agr E* and not before, he could get himself registered. This, said the President, was straight away a powerful incentive to membership recruitment in the Branches.

Something else that was new was the recent creation within the Institution of the grade of *Technician Associate*. This was now open to hundreds of agricultural engineering technicians of the City and Guilds 261 type (among others) who had been trained and employed in a technical capacity for three years or more. "This represents a huge, untapped, hitherto unrecognized level of engineering attainment within our industry", said the President. "Now we can offer a valuable form of membership to these people and once they are in as Technician Associates —and not before—we can register them as *Technicians (CEI)*. There is another powerful string to our recruitment bow".

The President reminded members that the Council had promised it would not charge the usual £5 entrance fee to any person admitted as an Associate (whether General or Technician) in 1971. This illustrated the great importance attached to attracting new Associates as part of the Institution's growth pattern.

Mr Henniker-Wright paid warm tribute to the way in which the Branches efficiently controlled and administered the Institution's regional activities. He acknowledged that it meant much hard work by a few people, often unheralded and unsung. He concluded with the hope that the Branches would long continue the good work of keeping the Institution in prime condition as a flourishing, high-priority organization which would serve the industry well and of which every member could be proud.

□

BSI NEWS

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

Prices Up at British Standards

The British Standards Institution announced recently that the prices of all its publications, conversion devices, etc., have had to be raised by 15% with effect from 1 July. Since the former basis for pricing was fixed over 18 months ago, substantial increases in costs have occurred and these can no longer be wholly absorbed.

This measure will only be effective until the 1972 Yearbook is published early in March 1972. The 1972 Yearbook will contain completely up-dated prices.

In addition the Institution has found it necessary to compensate itself for the disproportionate costs of dealing with small orders. A 20p surcharge will be made on all orders whose nett value totals less than £2. These surcharges will not apply for conversion slides and the readimetric converter.

With the publication of the 1972 Yearbook, radical changes in BSI's selling arrangements, designed particularly to favour subscribing members, will be announced.

Subscribing Members of BSI enjoy the following benefits at present:

1. 10% discount is allowed on all orders and no charge is made for postage packing and handling;
2. Automatic free issue of the monthly journal, *BSI News*, and BSI Yearbook is made;
3. Credit accounts are confined to members; non-members have to send cash before publications can be despatched.

The Institution states that quite apart from information and participation in crucial industrial issues today, membership of BSI has definite financial advantages, which will be strengthened in 1972.

Comparative Evaluation of Machinery Vibration

In recent years the increasing power and speed of rotating machinery have brought the problems of vibration into great prominence. In many cases restrictions are being applied to the acceptable levels of vibration and it has become desirable for manufacturers of machinery to have a recognized method of providing information on the subject so that users will be able to obtain a valid comparison of one machine with another of the same type.

The new BS 4675 *Recommendations for a basis for comparative evaluation of vibration in machinery* provides a basis for specifying the rules to be employed in evaluating the mechanical vibration of machines in the operating range 10 to 200 r/s in a way that makes this comparison possible. The purpose of the rules is to evaluate the vibration of "normal" machines with respect to reliability, safety and human perception. Vibration severity is expressed in terms of r.m.s.—velocity values and examples of a recommended method of classification are given.

The recommendations are in accordance with agreement reached by a committee of the International Organization for Standardization (ISO) and shortly to be embodied in a draft ISO recommendation.

Copies of BS 4675 may be obtained from the BSI Sales Branch, 101 Pentonville Road, London N1 9ND. Price by post 60p (subscribers 50p). Remittance with order for non-subscribers.

Revised British Standard for SI Units

The definitive British Standard on the metric units which are the basis of the change to metric in this country has been revised and is published as BS 3763: 1970 *The International System of Units (SI)*.

The international move towards full adoption of SI units, no less than the practical application of them in this country as industry moves actively into the metric programme, has brought developments of a detailed character through resolutions of the Conférence Générale des Poids et Mesures (CGPM) and decisions of the Comité des Poids et Mesures. The BSI revision takes full account of these developments and is in alignment with the detailed informatory document issued by the International Bureau of Weights and Measures, the authorized translation of which is available through HMSO. The new British Standard incorporates in concise form the information promulgated by the International Bureau.

The importance of this publication is emphasized by the fact that Mr G. B. R. Feilden, Director General of BSI, took the chair of the committee responsible for producing the revision.

Copies of BS 3763:1970 may be obtained from the BSI Sales Branch, 101 Pentonville Road, London N1 9ND. Price by post 60p (subscribers 50p). Remittance with order for non-subscribers.

Hydraulic Field Spraying Nozzles

The British Standard specification for hydraulic spray nozzles used in insect, fungus and weed control, (BS 2968), was first published in 1958, with the main object of providing for interchangeability, both physical and functional, of spray nozzles of like size and type made by different manufacturers.

The specification is now being revised in several parts and BSI now publishes BS 2968: Part 1 *Field spraying nozzles* which specifies dimensions and performance requirements for spray nozzles of the cone spray and fan spray type for attachment to booms on ground crop sprayers. Metric dimensions have been used, where appropriate, as part of the national policy to change to the metric system.

Manufacturers and users have co-operated fully in preparing this document which it is intended should reduce unnecessary variation in manufacture, whilst not restricting design, and which will benefit the user and stockist by providing the interchangeability and functional qualities he needs.

The other parts will deal with strip and orchard spray nozzles.

Manufacturers of field spraying nozzles complying with BS 2968: Part 1 may apply to BSI to use the Kitemark. This is a registered trade mark used only on licence from BSI and its presence on an item or its package is an independent assurance that it does comply with a British Standard.

Copies of BS 2968: Part 1 may be obtained from the BSI Sales Branch, 101 Pentonville Road, London N1 9ND. Price by post 60p (subscribers 50p). Remittance with order for non-subscribers.

Essential Oils

A revision of the series of specifications published as BS 2999 *Essential oils* continues with the publication of the 1971 edition of those numbered 32–43 inclusive. These specifications were first published in 1963 and the present revision takes into account committee members' experience in conjunction with discussions at meetings of Technical Committee ISO/TC54—Essential Oils, of the International Organization for Standardization, held in the intervening period.

The requirements for the oils themselves have not been changed greatly from the previous edition but those changes which have been made have brought the specifications into line with corresponding documents being developed, or already published, by the international committee.

The opportunity has also been taken to bring the nomenclature and units up to date. For example, the expression "weight per millilitre" has been replaced by "mass per millilitre" in accordance with recommendations of the international committee concerned with quantities, units and symbols etc.

The system adopted for naming essential oils is given in the foreword to the first series of specifications, Nos. 1–15, the first revision of which was published in 1965. The name of the botanical authority responsible for the classification of the plant source is given in full, in place of the accepted abbreviations hitherto employed, with the sole exception of Linnaeus which is still abbreviated as "L". The botanical names and authorities are given as far as possible in accordance with the editions of the 10th International Botanical Conference at Edinburgh (August 1964) incorporated in the International Code of Botanical Nomenclature, (Utrecht 1966).

Work carried out after the publication of the most recent (1962) edition of BS 2073 *Methods of testing essential oils*, has shown that for oils containing tertiary alcohols an acetylation period of 16 hours is desirable when determining the ester value after acetylation by the dimethylaniline/acetyl chloride method and this period has been adopted for the relevant oils.

Attention is also drawn to the expression of the content of carbonyl compounds in terms of the carbonyl values only, unrelated to particular aldehydes or ketones. This decision has been put to the international committee on the grounds that it is inappropriate to refer to a particular compound when a number are known to be present, in view of the development of more refined methods for determining the content of particular compounds, especially gas-liquid chromatography. It is hoped that procedures for this technique may be included in future editions of BS 2073.

Manufacturers of essential oils complying with BS 2999/32-43 may apply to BSI to use the Kitemark. This is a registered trade mark used only on licence from BSI and its presence on an item or its package is an independent assurance that it does comply with a British Standard.

Copies of BS 2999/32-43:1971 may be obtained from the BSI Sales Branch, 101 Pentonville Road, London N1 9ND. Price by post 85p (subscribers 70p). Remittance with order for non-subscribers.

Revision of British Standard for Petrol Grading

The British Standard on which is based the immensely successful scheme for grading and marking petrol for retail sale has been revised and published as BS 4040:1971 *Petrol (gasoline) for motor vehicles.* The first issue was published in 1967 as BS 4040: Part 1, which dealt with the specification for petrol and it was intended at the time that Part 2 should give details of the test methods required. Since that time, however, many of the test methods have been published as British Standards and reference is made to them in the present revision.

The revision takes into account the changes in the ASTM/IP joint method for the determination of knock characteristics of motor fuels by the Research Octane Number (RON) method which requires the result to be reported to the nearest 0·1 RON. The minimum RON required for each of the grades of fuel are therefore now expressed as:

5 star	100·0 minimum
4 star	97·0 minimum
3 star	94·0 minimum
2 star	90·0 minimum

As a further control on volatility laid down in the standard, a maximum value of 220°C has been introduced for the final boiling point.

In order to facilitate the work of Weights and Measures Inspectors a new section has been introduced which discusses the interpretation of a single RON test result.

The committee intend to ensure that the standard shall continue to accurately reflect developments which are taking place in the motor and petroleum industries and for this purpose a study has been instituted of those properties of motor vehicle fuel which are related to its performance in modern multi-cylinder engines.

Copies of BS 4040:1971 can be obtained from the BSI Sales Branch, 101 Pentonville Road, London N1 9ND. Price by post 50p (subscribers 40p). Remittance with orders for non-subscribers.

Symbols for Communicating Information on Machine Tools

The safety and efficiency of all industrial machine operators depends directly on their complete and unhesitating comprehension of the controls and instrumentation at their disposal. Nowhere is this more true than in the machine tool industry, where the operator may have to control many complex machine movements and where a large international trade in machines and the increasing mobility of labour between countries often creates problems in the provision of exact translations in the working of written information.

A valuable solution is a universal system of easily recognized symbols which each have a precise meaning and can be combined in use to present a convenient and unmistakeable message. The British Standards Institution published a standard containing such a system in 1963 and it is now being re-issued in three Parts after a major revision and expansion of the contents. The first Part to be published is now available: BS 3641 *Symbols for machine tools:* Part 1: 1971 *General symbols.* Part 2 will deal with symbols for numerically controlled machine tools and Part 3 with symbols for specialist applications.

The revision was prepared at the request of the Machine Tools Trade Association, which desired the range of symbols to be increased to cover the latest technology in the field. Some of the new symbols in Part 1 are British in origin, whereas others have been adopted from overseas standards where appropriate.

An important concept behind this revision is the idea of a symbol language structured so that each unique

BSI News—*from previous page*

symbol can be combined with others to communicate any desired information in the simplest possible way. This approach permits the application of the system to new types of machine without the necessity to invent symbols specific to one particular machine or control.

The symbols in Part 1 are presented in six sections under the headings of Modes, Elements, Values, Actions, Safety and Status Indications, and Compound Symbols. An appendix gives examples of typical grouping of symbols from the different sections. The sizes and, to a certain extent, the proportions of the symbols may be altered at the designer's discretion in order to serve their purpose most effectively. The symbols are printed on a grid based on a basic module of 0·8 mm to aid the designer.

Although this standard has been drawn up by the machine tool industry and will find its primary use there, it is considered desirable that other industries should adopt symbols from it wherever possible in order to avoid conflicting approaches to the same problem. On the international level, the International Organization for Standardization recently formed a co-ordinating committee for all work on symbols, with a view to promoting just such uniformity of approach in different industries, and the UK is keeping well in step with this work.

Copies of BS 3641 : 1971 can be obtained from the BSI Sales Branch, 101 Pentonville Road, London N1 9ND. Price by post, £1·40 (subscribers £1·20). Remittance with orders for non-subscribers.

Bourdon Tube Pressure and Vacuum Gauges

The British Standards Institution has published BS 1780 *Bourdon tube pressure and vacuum gauges:* Part 2 : 1971 *Metric units.* This standard relates to gauges for general industrial use and to test gauges and it is supplementary to BS 1780, which is in imperial units. As with the imperial version, Part 2 includes a number of tables of dimensions and graduations, the principle purpose of which are to achieve interchangeability of gauges of a similar size and type.

In preparing this part of the standard particular consideration has been given to the choice of units for expressing pressure especially with regard to marking the dials of pressure gauges. For the purposes of this standard it is considered that the bar (1 bar $= 10^5$ N/m^2) is a more practical pressure unit than the derived SI unit, the N/m^2, which is very small. This part of the standard accordingly gives first preference to the use of the bar, but does not preclude the usage, if so desired, of N/m^2, the kN/m^2 or the MN/m^2. With gauges manufactured to this standard a reading of zero bar is atmospheric pressure.

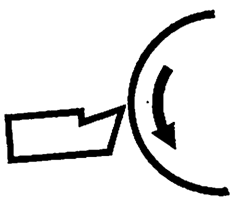
This standard applies to indicating pressure gauges, vacuum gauges and combined vacuum and pressure gauges (compound gauges), of the Bourdon tube type (with C, or helical or spiral tube forms) from 50 mm to 300 mm nominal size. The gauges are suitable for industrial and marine use with the common industrial fluids such as air, oil, water or steam.

Precautions are outlined in appendices relating to special cases such as gauges for high pressure gases, and gauges for use with oxygen and acetylene. The information which it is necessary to supply when ordering these instruments is listed.

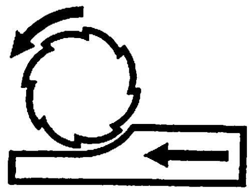
Copies of BS 1780 : Part 2 : 1971 can be obtained from the BSI Sales Branch, 101 Pentonville Road, London, N1 9ND. Price by post £1·05 (subscribers 90p). Remittance with orders for non-subscribers.

Some examples of symbols from BS 3641 : 1971.

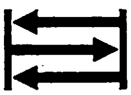
Drilling



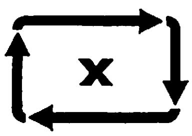
Turning



Conventional milling

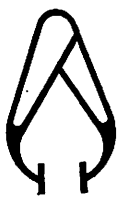


Oscillating rectilinear motion

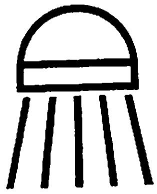


Automatic

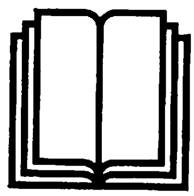
Manual



Gauge size external



Work area illumination



Refer to instruction book

Hydraulic Cylinders for Agricultural Machinery

The British Standards Institution has published BS 4742 *Hydraulic equipment for agricultural machinery:* Part 1 : 1971 *Cylinders*, which is the first Part of a comprehensive British Standard, which will, it is intended, cover all the necessary aspects of hydraulic equipment for agricultural machinery.

Part 1 specifies the essential dimensions and operating requirements for single-acting, double-acting and telescopic hydraulic cylinders for use in agricultural machines operated in conjunction with tractors whose hydraulic systems comply with BS 1495.

Recommendations for the testing of cylinders are also included. Remote cylinders supplied with tractors for use with various agricultural machines are not covered.

The main purpose of the standard is to reduce the number of types of hydraulic cylinders at present in use on agricultural machinery, so as to provide a limited and rational range from which the manufacturer can choose a suitable cylinder to cover existing and foreseeable requirements.

It is recognized that some existing designs and practices will continue to be used until they become obsolete, but it is hoped that the adoption of this standard for new designs and developments will simplify design, manufacture and stockholding, and so benefit the user by lowering costs, making it easier to obtain replacements, and promoting a degree of interchangeability.

Parts 2 and 3 of BS 4742 will deal with hydraulic motors and pumps, respectively.

Manufacturers of cylinders complying with BS 4742: Part 1, may apply to BSI to use the Kitemark. This is a registered certification mark obtainable only under licence from BSI, and its appearance on an item is an independent assurance that it does comply with this standard.

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Engineering Aspects of Green Crop Conservation

SILAGE SYSTEMS— PRACTICAL MECHANISATION ASPECTS

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1. Introduction

Our terms of reference are to cover various aspects of mechanisation involved in grass silage making, but it would be unreasonable to go into these aspects without first considering some of the more important research work that has been done recently. We have summarised the present state of knowledge on such matters as losses in conservation, timeliness of cutting, the use of additives, pre-cutting for wilting, and the value of consolidation and sealing. These factors influence the type and performance of the machinery finally chosen.

1.1 Losses in Conservation

The relationship between dry matter percentage of harvesting and conservation losses, summarized in Fig. 1, indicates that field losses increase as the material dries but in-silo losses decrease.[1] Overall losses therefore generally decrease but attempts at wilting in a wet climate do not necessarily reduce total losses and have in some seasons increased them. This has been illustrated in results from 12 silages which were made in 120 ton bunker silos over three seasons at Liscombe (Exmoor) E.H.F.[2]

1.2 Timeliness of cutting

Fig. 2 illustrates a typical pattern of spring growth of S.24 perennial ryegrass sward, not grazed after early April. As the grass grows the weight of crop dry matter increases, slowly initially, then rapidly as the stems grow and ears emerge, and finally more slowly as the ears begin to ripen in June. At the same time the feeding value decreases in terms of both digestibility (D value) and crude protein content. Spring growth pattern differs between seasons, and the date of ear emergence varies accordingly. However, in all seasons, the D value of 65 per cent for S.24 is reached about one week after EE. For most purposes a D value of 60 to 65 per cent offers a reasonable compromise between yield and quality.

1.3 Use of additives and wilting

Young spring herbage and leafy autumn aftermaths are often low in sugar and high in protein content and so they are unlikely to make stable silage as only small amounts of acid are produced in the fermentation process.

Results from several investigations at Liscombe E.H.F. have shown that good fermentation is possible provided that about 2½ per cent of the fresh weight of the crop is soluble carbohydrate. Where a low figure needs raising to a safe level ½ per cent of soluble carbohydrate can be equated with approximately one gallon of well mixed molasses or one-fifth to a quarter of a gallon of commercially available formic acid or one and one-third lb of Kylage per ton of herbage. The relationship between stage of growth, likely soluble carbohydrate content and the need for an additive are shown in Fig. 3.

Limited wilting and the use of an additive, or wilting to 25 per cent to 27 per cent dry matter has been shown to achieve the same final preservative action in experiments at many Experimental Husbandry Farms.[3,4,5,6,7] In a very wet climate at Liscombe E.H.F. on Exmoor, results of wilting on both young leafy herbage and more mature stemmy material were comparable with direct cutting and treating with appropriate amounts of molasses.

Wilting substantially reduces production of effluent and consequent loss of nutrients. The problem of safe disposal of the resultant liquor is also minimized.

1.4 Chopping, consolidation and sealing

Chopping and laceration release juices and improve consolidation which is important, especially with high dry matter forage, in controlling temperature and limiting the fermentation process. A study of consolidation and sealing at Drayton and Liscombe shows that in a leak-proof (vacuum) silo, slight reductions in dry matter losses were observed, but the plastic sheet had to be kept in close contact with the silage to minimize visible surface wastage. Jensen[8] who carried out trials in Denmark found that both evacuation and slight leaks were unimportant; gross flaws in the sheet could cause serious wastage, and he considered that in commercial practice plastic vacuum clamps were inferior to conventional bunker silos. More general observations have shown that both visible waste and in-store losses with silage in the 20–30 per cent dry matter range can be reduced by the use of a well sealed polythene sheet pressed firmly on to the silo surface.

Practical mechanization aspects of bunker and tower silage production will now be considered against this background of experimental work. To avoid confusion over the suitability of particular machines for specific jobs, bunker, or clamp, silage and tower silage will be dealt with separately.

2. Mechanisation of Bunker and Clamp Silos

2.1 Direct cutting versus wilting

From a mechanisation viewpoint direct cutting simplifies management. Interruption by inclement weather is minimized and as fewer operations and machines are involved susceptibility to breakdown is reduced. Direct cut machines, usually of the simple flail or double-chop type are generally lower in first cost, less susceptible to damage, easier to operate and simpler and cheaper to repair.

Mowing for pre-wilting reduces the power required by the harvester and increases its output. A survey by ICI[9] indicated that, although a pre-cutting operation is involved, the number of man hours per ton of dry matter ensiled was generally lower for wilted than for direct-cut silage (Table 1).

TABLE 1

Labour requirements, wilted and non-wilted silage

Tonnage	Hr/ton of silage		Hr/ton of silage DM	
	Wilted	Non-wilted	Wilted	Non-wilted
0–250	1·38	1·11	5·60	5·95
251–500	1·04	0·87	4·55	4·70
500+	0·80	0·80	3·60	4·00
Average	0·99	0·92	4·30	4·89

Both experimental findings and farmer experience show that it is reasonable to expect wilting to raise dry matter to a maximum of 30 per cent and one dry day is normally required for cutting and wilting prior to picking up. Local climate has a considerable influence on the time available in which to operate a wilting system. Meteorological data[10] from the Wiltshire Vale shows the number of 'pick-up' days available between 16 May and 7 June (Table 2) and indicates the difficulty of practising a wilting system during that period.

*Agricultural Development and Advisory Service.

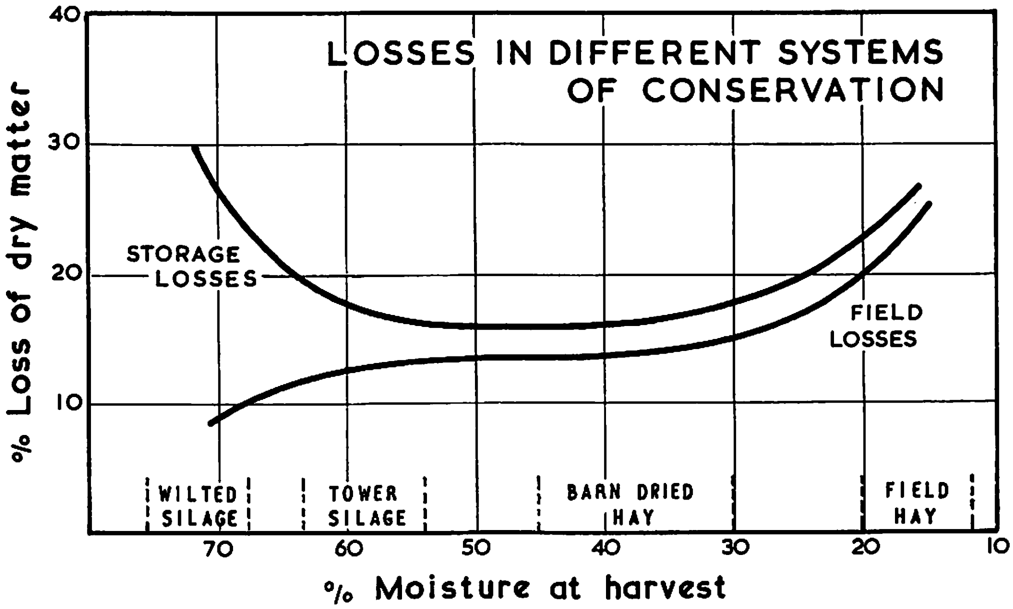
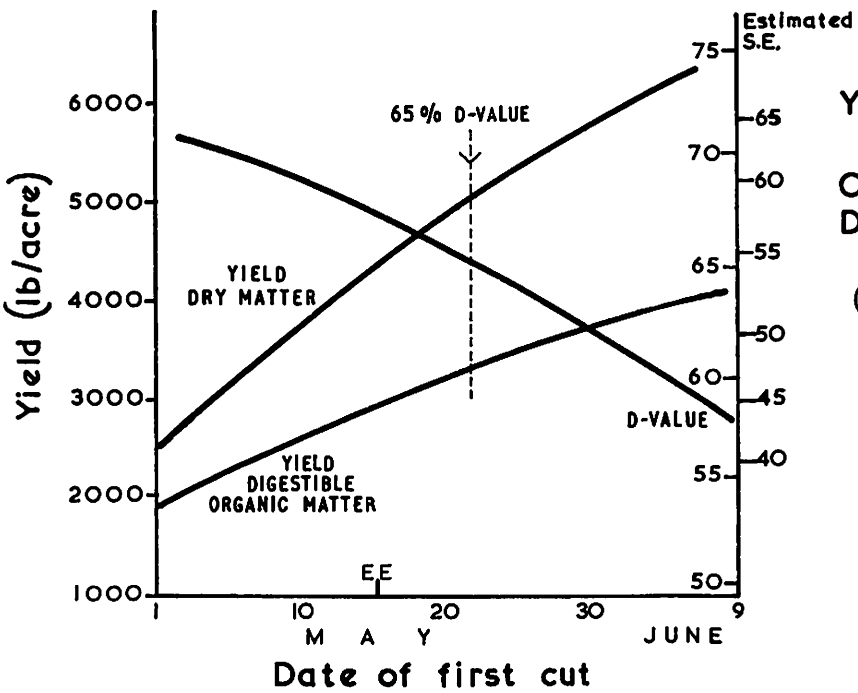


Figure 1



YIELD AND DIGESTIBILITY
(D-VALUE)
OF S24 PERENNIAL RYEGRASS
DURING FIRST GROWTH
IN SPRING
(100 UNITS FERTILIZER N/ACRE)

Figure 2

SOLUBLE CARBOHYDRATE
CONTENT
OF RYEGRASS/CLOVER
PASTURES
AT LISCOMBE E.H.F

Figure 3

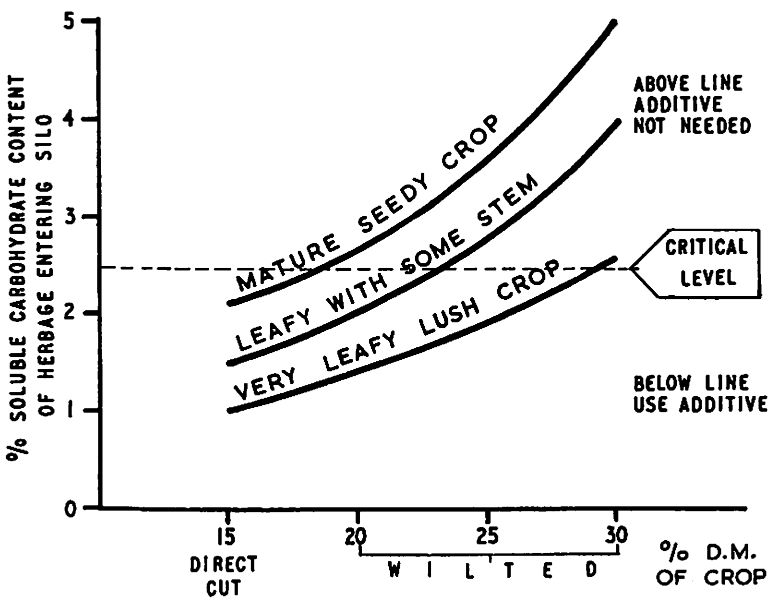


TABLE 2

'Pick-up' days for wilted silage 16 May–7 June—1947–1966

Average number of 'pick-up' days—9·5.
Greatest number of 'pick-up' days—17.
Lowest number of 'pick-up' days—2.
1 year in 4, 11 or more 'pick-up' days available.
3 years in 4, 7 or more 'pick-up' days available.
19 years in 20, 6 or more 'pick-up' days available.

When the crop reaches the stage of optimum digestibility and climatic conditions prevent wilting, experimental and practical evidence indicates that the crop should be ensiled with a suitable additive.

The mowers at present available can be briefly categorized as finger-bar, combined finger-bar/crimper, flail and horizontal rotary, and they are discussed in Section 3. The future requirement would seem to be some form of horizontal rotary mower with a conditioning device attached.

2.2 Types of Forage Harvesters

The types available are summarized in Fig. 4.

Flail harvesters are cheap in capital and running costs and the most reliable of all types available. Test reports indicate specific outputs of about 0·5 ton/h per hp applied. These easily operated machines are best suited to direct cutting of grass although they are least efficient in terms of weight of dry matter carried in transport vehicles. Buckraking the tipped loads of forage at the pit may be a bottleneck and in practice hand labour is often required to achieve satisfactory spreading. Flail harvested material is well suited to self-feeding, at heights of up to 5 or 6 ft and it can be knife-cut and easy-fed or removed by a level pronged loader; pre-cutting is unnecessary when using a grab type loader. Some forage boxes are not suitable for handling silage harvested in this way.

Double chop harvesters were designed basically for direct cutting and have similar specific outputs to flail harvesters. Pick up of a wilted swath can be satisfactory, provided that the flails undercut a long stubble, left by a mower of matching width, and provided wilting has not been excessive. Double-chopping of material improves trailer load weights (Table 3) and also ease of ensiling. Because the chopping mechanism is not of the metered-feed type the resulting staple length of the silage is variable and consequently best suited to self-feeding systems although mechanical outloading and feeding is possible. Running costs, susceptibility to damage and necessary maintenance are intermediate between flail and precision-chop type machines.

Precision-chop, or metered-feed, harvesters can be fitted with direct cut attachments but they are rapidly increasing in popularity as pick-up machines for making wilted silage. Specific output is usually about 0·75 ton/h hp applied, indicating a performance some 50 per cent better than flail and double-chop machines when the latter are direct cutting; in practice, however, rates of field clearance are often doubled. In the Spring of 1969 checks were made on several farms which changed from flail or double-chop machines (direct cutting) to full-chop harvesters, and the findings[11] confirmed worthwhile gains in performance. A second major advantage is the easing of transport problems. Thirdly, chopped forage is ideal for handling with a push-off buckrake. Short chopping also greatly assists consolidation and exclusion of air, while the resultant silage is easy to outload and feed mechanically.

2.3 Transport

The present trend towards larger capacity trailers allows a small number of tractors and drivers to keep pace with high output harvesters and counteracts the effect of long haulage distances. In deciding on the upper limit of trailer size consideration should be given to horse power of transport tractors, steepness of sloping fields, the wheel loadings that heavy soils can withstand, and the drawbar weight that the harvester can reasonably carry without breakage, or serious wheel sinkage when rear-loading.

The chosen harvesting system has considerable influence on load weights. Figures in Table 3, which applies to grass only, can be used as a rough guide in assessing the total and dry matter weight carried per load when employing varying degrees of wilt, chop length and trailer size.

2.4 Ensiling the forage

2.4.1 *Choice and operation of buckrakes and loaders*

In addition to the low cost rear-mounted buckrakes, both push-off and front mounted buckrakes have been introduced with the aim of reducing labour requirements or increasing the ensiling rate to keep up with the performance of modern harvesters.

The rear-mounted push-off buckrake provides a more positive discharge and shows to most advantage when working on a steep 'Dorset Wedge', or when handling metered-chop material, since the discharge action gives efficient spreading as the tractor moves forward. In the latter case the need for hand spreading can be completely eliminated.

To make the best use of a rear-mounted buckrake the tractor must have good stability and traction, adequate horse power, rapid lift linkage movement and suitable reverse gear ratios.

The main advantages of a front-mounted buckrake are that the operator can see his work more easily and forage can be placed on the silo with more accuracy. Discharge is more positive because of the increased lift and height obtained with a foreloader. The three basic methods of discharge are, mechanical trip, hydraulic angling and hydraulic push-off, but a combination of hydraulic angling and hydraulic push-off is also used. To ensure positive loading and retention of forage on the tines some front-mounted forks can now be fitted with hydraulically operated crowding grabs.

Efficient operation of a front-mounted buckrake requires a tractor of at least 60 hp, with power steering, oversize front tyres, and a large counter-balance weight. Twin rear wheels or 4-wheel drive also improve traction and stability. Industrial tractors fitted with hydro-kinetic (torque converter) transmissions, heavy duty foreloaders and high performance hydraulic systems, are well suited to silage clamp work. The new price of such tractors is high, but second-hand machines might be justified.

To achieve the maximum ensiling rate with any buckrake or loader the arrival and discharge point of incoming trailer-loads of forage should be positioned to avoid interruption of the work-cycle.

The forage pick-up point should have a hard level surface with a backwall or barrier to push against. Where necessary the clamp should be provided with safety rails and the working surface of the forage should be kept smooth and devoid of soft pockets to ensure safe movement of the tractor, as well as even and controlled fermentation of the silage.

The introduction of very high-reach foreloaders has led to some operators ensiling forage entirely from ground level and working to a near-vertical face. From an operational viewpoint the method is attractive but its success in terms of well-made silage depends upon adequate exclusion of air from the ingoing material which in turn depends upon moisture content, chop-length, maximum ensiling height and self-consolidating effect, as well as rapid sealing of the clamp as work progresses.

2.4.2 *Forage blowers*

The increased use of tower silage systems has demonstrated that forage blowers, evenly fed by dump boxes or forage boxes, are capable of handling well wilted metered-chop forage, at fairly high rates in terms of dry matter ensiled per hour.

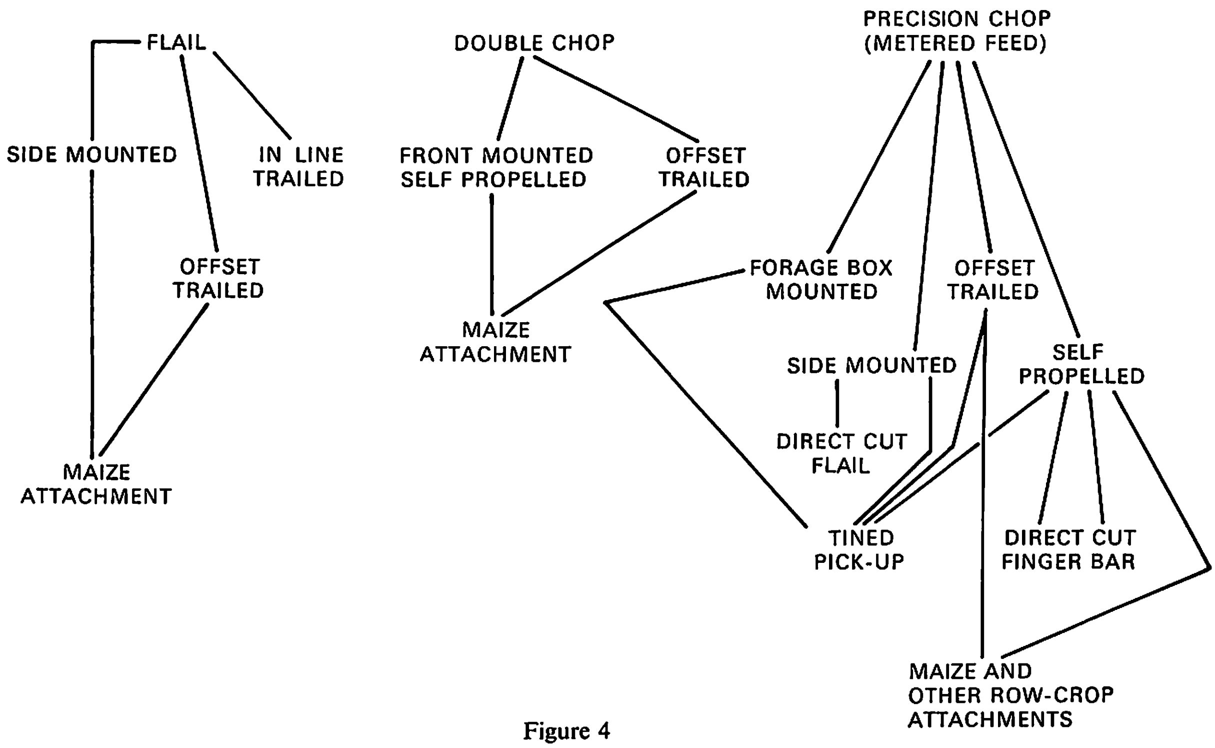


Figure 4

Successful application of this equipment to loading bunkers is possible provided that the forage is wilted to 25 per cent to 30 per cent dry matter and chopped consistently short. However, the length of horizontal throw achieved by blowers can be disappointingly low when compared with the vertical throw on tower filling operations and this should be borne in mind at the planning stage.

Where possible the blower should be close to the area of bunker being filled and this may add complications in terms of positioning the driving tractor and dump box especially as trailers tipping into it require considerable headroom. The need for a blower with chain-trace feed or a dump box with reversed cross conveyor discharge may arise. If forage boxes are used to feed the blower, then adequate room must be left for manoeuvring these vehicles. Meeting and over-coming all these problems is preferable to siting a blower so that the length of throw limits output.

The use of a blower for bunker silage generally implies that the forage must be self-consolidating. To obtain a limited fermentation and good silage, filling must be done as evenly as possible by frequent movement of the blower discharge hood.

2.5 Outloading and feeding

Mechanized feeding allows silage to be stored at a greater depth than the 5 to 7 ft commonly used for self-feeding, provided the silo walls have adequate strength to resist the loads imposed by the material and associated machinery, and it also allows the addition of cereals to the silage

TABLE 3

Effects of wilting and chopping on trailer loads

Dry matter of Crop			Direct-cut 20% dry matter		Wilted 30% dry matter			Wilted 40% dry matter
Harvester used			Flail	Double chop	Flail	Double chop	Metered chop	Metered chop
	10 ft × 6 ft × 6 ft	Total load weight, cwt	30·0	50·0	30·0	45·0	50·0	35·0
		lb/ft³	9·3	15·5	9·3	14·0	15·5	10·9
	360 ft³	Total weight of dry matter, cwt	6·0	10·0	9·0	13·5	15·0	14·0
		lb/dry matter/ft³	1·8	3·1	2·8	4·2	4·6	4·3
		Loads/acre with 10 ton crop at 20% dry matter	6·7	4·0	4·4	3·0	2·7	2·9
Trailer size and load details	12 ft × 7 ft × 6 ft	Total load weight, cwt	42·0	70·0	42·0	63·0	70·0	49·0
		lb/ft³	9·3	15·5	9·3	14·0	15·5	10·9
	504 ft³	Total weight of dry matter, cwt	8·4	14·0	12·6	18·9	21·0	19·6
		lb dry matter/ft³	1·8	3·1	2·8	4·2	4·6	4·3
		Loads/acre with 10 ton crop at 20% dry matter	4·7	2·8	3·2	2·1	1·9	2·0
	16 ft × 6 ft × 6 ft	Total weight load, cwt	48·0	80·0	48·0	72·0	80·0	56·0
		lb/ft³	9·3	15·5	9·3	14·0	15·5	10·9
	576 ft³	Total weight of dry matter, cwt	9·6	16·0	14·4	21·6	24·0	22·4
		lb dry matter/ft³	1·8	3·1	2·8	4·2	4·6	4·3
		Loads/acre with 10 ton crop at 20% dry matter	4·2	2·5	2·8	1·9	1·7	1·8

ration. The silo need not be sited near the cattle sheds, and so cattle and vehicles do not impede one another during silage making.

Three types of machinery are currently available for outloading.

Fore-loaders or rear-loaders fitted with a buckrake can be used for silage made with any type of harvester. Flail cut or double-chop silage must generally be cut vertically across the working face into strips about 3 ft wide using a motorized silage knife or power saw. The 9 in. deep strips of silage so formed can then be subdivided across the width of the silo into blocks which are slightly wider, say 6 in., than the buckrake or fork being used for outloading. This implement, with its tines held horizontal by a parallel linkage or double-acting hydraulic ram, can then be used to pick up the blocks and transfer them directly to the feed manger or indirectly via a transport vehicle or feeding mechanism.

The fore-loader-mounted hydraulically operated silage grab obviates the need for pre-cutting of flail or double-chop materials, and can extract these and full-chop silage straight from the bunker.

A buckrake with very short tines, or a manure fork can be used for direct extraction of full-chop silage. In some instances double-chop material, chopped with a well maintained six blade flywheel can be removed in this way, but a lot more digging and tearing at the working surface will usually be necessary for each forkful obtained.
In many situations the addition of a rotary grapple or hydraulically operated crowding grab boosts the performance of a fore-loader and fork. A slew-loader with a suitable grab can achieve the same results as the grab on a foreloader but with less wear and tear on the operating tractor.

In using any of the above outloading methods, which tend to leave a ragged working surface, every effort should be made to minimize the ingress of air and likelihood of secondary fermentation between successive unloading periods. This can be assisted at the planning stage by keeping the cross-sectional area of the bunker to a practical minimum. At the harvest stage avoidance of over-wilting, not more than 27 per cent to 30 per cent dry matter, short chopping with a full-chop harvester, and ensiling to a settled depth of at least 10 ft all help. At the unloading stage the working surface should be left as smooth and even as possible, and if practicable, should be covered with a polythene sheet, especially if the bunker is unroofed.

At present the only purpose-built bunker silo unloaders commercially available in the UK are imported machines. They are tractor powered with auger or chain and flight or cylindrical tined cutting heads which swing in a vertical plane and tend to leave a slightly curved near-vertical unloading surface. The cutting head feeds the silage back either to a blower or chain and flight conveyor which can in turn load a trailer or forage box.

As with the tower silo unloaders first imported into this country the performance of these bunker unloaders is not likely to be nearly as good when handling grass silage as it is when handling ensiled lucerne, maize, or whole crop barley. Development work on new types of unloader is, however, in progress.

3. Production of Tower Silage

3.1 Loading rate and dry matter content

The main requirements for mechanization of tower silage are fast blockage-free cutting of the crop, rapid wilting to between 35 per cent and 50 per cent dry matter, short and consistent chopping of the forage to less than 1 in., a fast rate of tower filling matched to silo diameter, correct use of any spreading device fitted to ensure even loading of the tower. Conscientious use of all sealing devices to minimize ingress of air and consequent loss of nutrients is vital. If these criteria are observed then trouble-free unloading and feeding of the resultant silage will be achieved.

Rate of handling, to obtain a 10 ft depth of fill per 8 hour day is shown in Table 4:—

TABLE 4

Silo diameter ft	Floor area ft²	Approximate dry matter stored at settled height of 60 ft tons	Dry matter to be ensiled per hour tons	Total weight of silage to be ensiled per hour at 40 per cent dry matter tons
18	255	138	2·65	6·6
20	314	169	3·25	8·1
22	380	204	3·92	9·8
24	455	243	4·67	11·7
26	530	286	5·5	13·75
28	618	331	6·37	15·9

Adequate wilting is required in a tower silage system to ensure optimum performance of handling equipment, reduce pressure loadings on the structure, eliminate silage effluent and reduce corrosion. Target figures for dry matter content are:—

	Minimum	Optimum
Top unloaded tower	35 per cent	35–45 per cent
Bottom unloaded tower	40 per cent	40–45 per cent

Very wet forage leads to damage or possibly even collapse of the silo, and causes unloading difficulties. Very dry forage also leads to unloading difficulties with some unloaders, but the risk of overheating and the possibility of spontaneous combustion is a more serious problem.

3.2 Mowing for wilting

Before laying up fields for silage the land should be heavily rolled in the Spring and any serious mole infestation cleared to minimize damage to field machinery and soil contamination of the silage.

Rate of mowing and conditioning should match the ensiling rate and whilst the wilting rate must be fast enough to reduce the loss of dry matter in the field any temptation to get too far ahead must be avoided. Efficient operation and maximum output of the forage harvester will be obtained by presenting a thick swath to the pick-up.

A finger-bar mower followed immediately by crimping, crushing or tedding has the lowest tractor horse power requirement of any conditioning system, but frequent knife blockage results in very uneven swathes and too low an overall rate of work to keep ahead of the forage harvester. The more expensive double knife mower has a higher working rate in difficult conditions, but also leaves an uneven swath.

Flail mowers have the highest horsepower requirement. Adequate power must be available to maintain the correct rotor speed at a fast forward speed to avoid over-laceration of the crop which causes leaf shatter and can also reduce the 'flow' characteristics of the resultant silage despite correct chop-length.

Rate of wilting of a flail mown crop can be very rapid and overwilting, particularly of flail mown grass, leads to problems of gum build-up and seriously impairs the performance of the forage blowers and fan-type unloaders. Rotary mowers, whether of the single rotor or multiple disc or drum type, have a high cutting speed and power requirement intermediate between the finger-bar mower and flail. Their conditioning effect on the swath is negligible and for rapid wilting it is necessary to follow (in the reverse direction for good pick-up), with suitable conditioning equipment. Reliability of some newly-developed machines is questionable at present.

Trailed and self-propelled combined mower-crimpers in working widths of 7 to 10 ft can achieve sufficiently high rates of work, under the right crop conditions, to justify their high cost for the large scale operator. Swath size tends to be a better match for the full-chop harvester compared with the swaths of narrower mowers, but drying of a deep heavy swath can be disappointing and the machines which leave a wide evenly spread and crimped swath provide the highest wilting rate.

3.3 Forage harvesters

Short chopping is normally carried out in the field to impart 'flow' characteristics to the material for subsequent handling, to pack the maximum amount of material into transport vehicles and to ensure the maximum capacity and self-consolidation of forage in the tower. Reference has already been made to precision chop harvesters (Section 2) and the choice of mechanisms lies between cylinder chopping and blowing, cylinder chopping and flywheel blowing, and flywheel chopping and blowing. These machines are fully described in Mechanization Leaflet 13.[12]

The most important factors to consider in choosing a particular type are the power requirement and output, ease of blade sharpening, setting and replacement, and susceptibility to blockages, damage by stones and other foreign material. Suitability for side or rear loading, delivery height and availability of alternative front-end mechanisms, automatic hitches and twin wheels must also be considered.

3.4 Transport and off-loading

Self-unloading forage boxes or tipping trailers used in conjunction with a dump box, are suitable for feeding the blower with chopped material. The forage box system ensures large load capacity and quick and simple positioning for unloading. Vertical loadings on the drawbar are negligible with four wheeled boxes.

A tipping trailer and dump box has a lower capital outlay and less is tied up in specialized equipment; if well balanced this system allows continuous operation of the blower whereas a forage box system implies idle periods between each load. This can be important if the blower is the potential bottleneck.

The dump box system can be used in many ways depending on the type of dump box, layout of silos, positioning of blower and changes in ground level. Quick turn round of transport vehicles is vital and although this depends very much on driver's skill it can be assisted by the use of a dump box with a conveying floor which permits the transport vehicle to be reversed on to it for complete and quick discharge of the whole load inside the dump box body. Wheel ramps or changes in ground level can be used to raise the transport vehicle for rapid discharge of the complete load, but very short steep ramps can reduce tipping angle of the trailer to the point where load discharge may be adversely affected. Reversing and manoeuvring time can be saved by using side tipping vehicles where ground levels permit. The most rapid turn round of all can be achieved by installing a concreted tipping area where the forage is simply tipped for subsequent loading into the dump box by tractor loader and buckrake.

3.5 Choosing and using a forage blower

High output is obviously a major consideration but observations indicate that choice of a particular type or make of machine has much less influence on output than correct use of the blower in terms of impeller speed, horsepower applied and evenness of feed. Moisture content and chop length of the forage, silo height and diameter, method of spreading, interior smoothness and straightness of the pipe run, and adequate provision for exhausting forage-entrained air are all further important factors. Other points for consideration include the ability of existing power units to be matched to the required impeller speed and also the direction of rotation, if for example a secondhand lorry engine and gear box unit is to be used. Silo filling-door position and required position of blower and dump box or forage box in line with it are important in terms of blower intake-hopper position and the possible need for chain-trace intake or reversed cross-conveyor on the forage or dump box.

In some seasons, particularly when grass has been severely conditioned and heavily wilted, a black gummy deposit may build up on the working surfaces of the blower. This can seriously impair performance but is easily removed by dribbling in small amounts of water from a hosepipe, or by using pipe tappings specially fitted to allow connection of a continuous supply. The small amount of water required has a negligible effect on the overall moisture content of the forage.

3.6 Silage spreaders

Some means of spreading to load the silo evenly with chopped forage is essential to obtain maximum capacity, an even pattern of consolidation which ensures even wall loadings, controlled fermentation and improved unloader performance.

Manual labour is seldom used because the job is unpleasant and dusty. It can also be dangerous, due to gas formation in a confined space, especially if attempted several hours or days after filling. Valuable filling time can be wasted by spreading at intervals during the loading period and this method of levelling still tends to leave an uneven compaction pattern.

Almost all new silo installations employ either a revolving plate, moving hood or top unloader 'in-reverse' type of mechanical spreader.

The first two types are designed to spread the forage in a peripheral strip around the wall of the silo because a large proportion of the floor area occurs in such a strip (Table 5). Forage well packed against the wall prevents ingress of air and consequent wastage and most top unloader wheels normally follow this peripheral path and require a firm surface on which to obtain traction.

TABLE 5

Silo diameter	Width of strip around silo perimeter which contains half of total floor area
18 ft	2 ft 8 in.
20 ft	3 ft 0 in.
22 ft	3 ft 3 in.
24 ft	3 ft 6 in.
26 ft	3 ft 10 in.
28 ft	4 ft 1 in.

Further information on silage spreaders is available in the short term leaflet 'Mechanized Handling and Feeding of Tower Silage'.[13]

3.7 Silage unloaders

The broad choice is between top and bottom unloading. Top unloaders can be categorized as follows:—

(*a*) Auger and fan type: (i) Single auger.
(ii) Double auger.
(*b*) Double auger and central flue to bottom conveyor.
(*c*) Chain and cutters with internal side chute.

Bottom unloaders have either a rotating or a swinging arm with chain and cutters.

Advantages and disadvantages of the two main types are well known and have been detailed in the short term leaflet 'Mechanized Handling and Feeding of Tower Silage'.[13] This reference also covers the main operational problems. In planning any tower silo installation one of the first and most important factors to consider is the adequacy or otherwise of the electrical power supply. Any deficiency must be rectified at the outset if satisfactory unloader performance is to be achieved.

In practice the two major factors affecting performance and ease of operation are the condition of the forage and the evenness of spreading achieved at filling time.

4. Conclusion

4.1 Sound management

This paper sets out some of the more important practical mechanization aspects of making both bunker and tower silage. However, the potential economic success of any theoretically sound silage conservation system can only be realized in practice by sound management of all the resources involved—the crop, the machinery, the storage structure and the men running the system. The responsibility for this clearly lies with the farmer.

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Engineering Aspects of Green Crop Conservation

FUTURE DEVELOPMENTS IN THE PRODUCTION AND HANDLING OF HAY

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1. Introduction

For the past two decades considerable effort has been put into developing new methods of producing hay. Farmers, manufacturers and research workers have solved parts of the overall problem, but a universally acceptable haymaking system which combines improved quality of product with a significant reduction in handling costs has yet to be developed. There are two main reasons for this.

Firstly there has been a general assumption that the proportion of forage conserved as hay would decrease rapidly to be replaced by the production of silage or artificially dried grass. Secondly, farmers have been reluctant to invest much capital in hay conservation because the product has been regarded as a maintenance roughage which shows little return on investment. A combination of cutting over-mature crops and the concept of cheapness of production has therefore led to the vicious circle of high losses and low nutritive value of the product.[1] A third reason, even for the farmer who wishes to invest capital to improve his quality of product, must be that many of the developments in this 20-year period, although individually of significance, have either not been capable of full integration into a complete farm scale conservation system, because they have been insufficiently developed to overcome the mechanical problems involved, or they have not represented value for money in terms either of the additional output of nutrients per acre or the labour economy which they could achieve.

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The purpose of this paper is to identify the main problems from mowing to storage, summarize the more important results from experimental, research and development work, and to consider their potential application on a wider scale in the future.

The haymaking process can conveniently be broken down into three stages, in each of which there may be a deterioration in quality and an addition to cost which is not fully recoverable in terms of improved feeding value. The first stage is swath wilting, during which nutrient losses will vary from 10–30% of the total weight cut, and in which 1·5 to 3 tons or more of water is removed for each ton of hay made at 20% m.c. depending on the final method of disposal. Most hay at present remains in the swath, or in small heaps of bales, until there are only a few hundred pounds of water per ton of finally dried hay to be removed, and so the second stage to be considered will be methods of handling and especially those which are widely practised at present. During the swath wilting process and in temporary and final storage phases, much hay suffers considerable reduction in its protein and energy value; the third item to be discussed will therefore be ways in which losses can be reduced, particularly by removing the crop from the field at high m.c. Some of the techniques available make it possible to use more streamlined methods of handling.

2. Hay Drying in the Swath

Mechanical treatment of the swath is more severe than the hand applied treatments which it attempts to simulate[2] and this has led to a conflict between the benefits to be obtained in terms of a quicker drying rate, following early and often severe conditioning, and the disadvantages of mechanical leaf loss, coupled with leaching of soluble nutrients, such as carbohydrates and moulding of the crop, especially in store. Hence the returns from any engineering development designed to take advantage of short spells of fine weather, by input of power to accelerate drying rate, can be properly evaluated only in terms of measurement of both water and nutrient losses, made at all stages of production from mowing to feeding the crop.

Early experiments showed that although drying rates were easily increased the total loss of dry matter in the field could be as high as 45% when crimping, crushing and lacerating treatments were used, compared with a loss of only 25% following tedders and turners.[3, 4]

Further experimentation indicated that if attention was paid to the mechanical details of both primary and secondary treatments, particularly where adequate power was available to operate conditioning machines in the recommended manner, then benefits in terms of drying rate need not be matched with very high losses of plant nutrients.[5]

It was also usually possible to reduce the moisture content of heavily conditioned hay to a lower level than that of hay which had received gentle treatment.[6] The interaction between field treatment and losses in store must be appreciated to enable a complete evaluation of machine effects to be made.[7]

Most experimental results up to 1965 showed the advantages which could be obtained by the input of power into the swath wilting process, provided that proper machine management was practised. However, the techniques were not widely used because flail mowing treatments required more power than was available on many farms, whilst mowing and conditioning machines, which required lower power inputs, of less than 20 hp, were often badly matched and had a poor mechanical performance.

The recent development of alternative methods of mowing, such as the drum and disc rotary mowers, appeared to offer a solution to this problem. The most important advantage is reduced susceptibility to blocking which allows a substantially increased working rate when used in laid and tangled crops. Experimental results in 1968 and 1969 showed that they did nothing to increase the drying rate compared with conventional mowing and so some form of conditioning or modification to the mower, was still needed to obtain a satisfactory rate of loss of water. This series of detailed experiments [8, 9] paid attention to power input which in perennial ryegrass varied from as little as 0·7 hp/ft width of cut at 4 mile/h for a standard reciprocating cutter bar mower, up to 7·1 hp/ft width of cut for a 3 bank flail mower; there was a good correlation between specific power requirement and both rate of water loss and fragmentation of the crop. The cost of tedding and turning treatments, in terms of an equivalent amount of lost crop, was also calculated. Severe conditioning treatments, such as flail mowing, crimping, crushing and tandem tedding, saved on an average more than one pass through the crop, and it has been argued that if it costs from 50p to £1 per acre to apply a single secondary treatment, this is equivalent to 2½–5% of the yield in a 2 ton/acre crop with a value of £10 a ton.

Results of this work confirmed the earlier findings about drying rate, lower final m.c.% and yield of nutrients per acre and have led to suggestions for the development of modifications to conventional and rotary mowers to enable cutting and conditioning to take place simultaneously. Although severe mechanical treatment usually leads to a higher level of leaching of soluble nutrients, in the field, this was counter-balanced over a six months storage period after which the sugar content of the drier conditioned hay was never significantly lower than that of unconditioned hay; in 46% of all cases it was significantly higher.

Full details of drying rates, dry matter yield and crop quality, with supplementary measurements of cutting performance, power requirement and crop regrowth for 17 different mowers and mower conditioner combinations have been reported elsewhere.[9]

Briefly the main guides to future development, based on the conclusions drawn from this and earlier work can be summarized as follows:—

(i) Systems of conditioning based on the reciprocating cutter bar are the most efficient measured in terms of the drying rate obtained from a low specific power input, and flail mowers are the least efficient.

(ii) The input of high power to mowing and conditioning can save the cost of 1 or more secondary treatments and also reduce m.c. in the swath to a lower level, but there may be a penalty to pay in terms of loss of crop dry matter.

(iii) Increase in working rate can be obtained by mowing a very wide swath, but if this is then conditioned and reduced to half or one third of the original width of cut the effect of any conditioning is practically eliminated.

(iv) Horizontal rotary mowers with two or more cutting heads and a medium power requirement leave consistent and even stubble under difficult conditions, but the form of the swath may be unsuitable for rapid drying and they must be used in conjunction with some type of conditioner to achieve rapid drying rate.

(v) The effectiveness of any machine system must be evaluated in terms of both the cost of production and the yield and nutrient content of hay available for feeding at the end of a normal winter storage period.

The most successful mowing and conditioning treatments of grass crops in the future are therefore likely to fall into three categories. The first will have a relatively low power input, less than 14 hp/5 ft width of cut, and will consist of either a reciprocating cutter-bar, with a single or double knife, plus a flail device or tedder which removes the crop from the area of the knife, to prevent blockages, giving it a simultaneous light conditioning equivalent to a crimping or crushing. The latter treatments are ideal for lucerne and clover crops but the equipment available does not achieve a high standard of mechanical efficiency in many grass crops grown in the U.K. The second system, with an intermediate power input of 14–28 hp/5 ft width of cut, is likely to be a combination of a disc or drum mower with integral tedding or a light flailing device. For rapid mowing and drying of light crops, especially silage aftermath, with a minimum of subsequent treatment the power consuming flail mower will continue to be preferred as the third system, at least until satisfactory alternatives are fully developed. Although this treatment may lead to some additional swath losses, the value will often be re-couped in terms of reduced cost per acre in secondary treatment and also reduced losses of crop nutrients in store.

In practice a portion of any crop left behind on the field, and considered as a loss in experimental work, may be eaten by grazing animals.

3. Handling Hay

Many detailed studies have been made of systems of handling conventional bales[10, 11, 12] and advice has been given on a wide range of systems suited to most operating conditions.[13] There have also been studies of handling hay which has been chopped, packaged in large bales, and in wafers.

The main points about currently accepted methods are summarized here. Improvements in present equipment will undoubtedly bring about marginal increases in output of the best methods of handling the normal bale, and as there are now about 85,000 pick-up balers in use in England and Wales, it would be unrealistic to suppose that there will be a major swing to other methods of hay handling within a decade, even though few, if any, systems capable of operation with a small labouring force can work at an overall rate of the 400 or more bales per hour which the modern baler can produce. At present baling is often the sole mechanised part of hay handling, following which handwork accompanied by an elevator is commonly used, but in the future farmers will expect fully integrated systems capable of bringing a degree of mechanisation to all stages of handling from collection of the swath to feeding. These complete systems must be balanced so that the output of the whole operation is not limited to the output of the most ineffective stage, and the equipment must be mechanically reliable.

The following factors affecting the choice of a suitable system for a particular farming enterprise, apply both to bales and alternative methods, and are given here as a background against which to assess new developments:—

(i) Tonnage of hay to be handled in a fixed period of time, to avoid deterioration in quality between collection from the swath and removal to temporary or permanent storage.
(ii) Labour force available at peak periods.
(iii) Practicable level of capital investment in tractors, trailers and in specialised equipment which both reduces manual effort and speeds up rate of work.

One-man operated systems can give a very favourable output in terms of tons handled per man hour, but they may well be too costly for the farmer with a small tonnage; if operated by only one man on a farm with a large acreage they often have a too low overall working rate to ensure that all crop is handled within the critical period. Hence total cost per bale moved, in terms of capital and labour input, although important as a datum line, is a poor measure of performance unless it is equated to quality of the final product. It follows that the most technically efficient system, measured in terms of man/min/ton handled, is not necessarily the best where a large quantity of hay has to be protected from the weather, and where labour or machinery can be made available to speed up overall working rates. Even so, future requirements are likely to favour those low labour and high capital input systems which can clear a large tonnage quickly with few men.

There are supplementary factors to be considered however, before finally selecting a system, some of which either necessitate breaks between successive handling stages, or require the introduction of other processes such as drying.

These include:—
(i) The frequent need for a reasonably weatherproof temporary holding stage in the field, prior to final storage. For example, baling may have to be followed immediately by a method of grouping which may or may not be an integral part of the handling system.
(ii) Field size and topography, which has a bearing both on size and suitability of acceptable handling equipment.
(iii) Within existing buildings accessibility often limits the choice of equipment and with some systems, based on unit loads of a specific size, reduction of the effective storage space may be an important consideration. Provision of specialist buildings for any handling system will increase depreciation costs which must be offset against savings in labour.

3.1 Full length bales

There are at present at least six different methods of handling immediately behind the baler, and a similar number of separately identifiable ways of transporting to the barn, where there are no fewer than four ways of transferring the load from the trailer or carrier into store. Various combinations of the methods of grouping, hauling and unloading are used, often without any real attempt to match one stage to the next, and hence a stage capable of dealing with only 150 bales/h may be associated with another stage in which 400–500 bales/h can be handled. Any attempt to build up a balanced system from such variable working rates leads to output of the whole operation being reduced to that of the worst stage, unless there are natural break points within the system. Manned sledges for example can be used to stack in any form suitable for the next stage of handling but their use will reduce baler output by as much as 15–30 per cent.

Any system involving the formation of unit loads must allow unrestricted output from the baler; this is possible with random collectors, now enjoying increased sales at the expense of manned sledges.

A significant factor in all measurements of output has been the importance of trailer size in any system. For journeys over half a mile each way, a capacity of 160 bales or more is to be preferred. Shorter journeys than this are economically possible with direct haulage using buckrakes or similar carriers. Many of the points raised are emphasised in the following figures built up from stages of recorded systems of handling (Tables I and II).[13]

A. Low capital cost system

Baling followed by handwork and elevator assistance at the barn.

TABLE I

		Output	
	No. of men	Man min/ton	Bales/h
Baling—dropped singly	1	8	370
Loading—hand pitching	3	36	250
Transport—large trailers	1	6	500
Unload and stack—elevator	3	25	360
Total labour cost		75	

Although unit cost in terms of labour is high and bales are not grouped into a temporary weatherproof storage, output can also be high if enough men are available; the total cost is kept down by low investment. The future cost and limited availability of labour will however make mechanisation beyond the baler a necessity.

B. High capital cost system

TABLE II

		Output	
	No. of men	Man min/ton	Bales/h
Baling & arranging—accumulator	1	10	300
Loading—Impaler loader to trailer	1	12	250
Transport—large trailers	1	6	500
Unload & stack—Impaler loader	1	10	300
Total labour cost		38	
Intermediate field stacking	1	8	
		46	

Labour cost per ton is clearly much reduced but overall output of bales carted and stacked per hour would be comparatively low unless the special type of loader required were available for simultaneous use in the field and at the store. Additional cost of handling, probably 7–9 man min/ton might be necessary to stack bales into temporary weatherproof heaps of 64 between baling and final removal to store.

Comparisons of this kind can only be a rough guide to potential output since in practice the lowest time cost of the poorest systems can be better than the mean results achieved by the best systems; hence it may be concluded that good management often masks the inherently high cost of inferior systems[11]. System outputs given on the basis of man min/ton can also be misleading partly because the weight of bales is often inaccurately assessed and partly because output in tons/h, as opposed to bales/h, is very much dependent on bale weight, especially where automatic sledges and tractor loaders are used for all stages. There seems to be no reason to doubt that the proper application and future development of systems of bale handling can lead to an increase in overall rate of baling and hauling of hay from the worst of about 0·8 tons (40 bales)/man h to a level of at least 1·5 tons (75 bales)/man h. Recently obtained figures using a flat eight system, with bale weights of 50 lb and a large trailer to haul about half a mile to a dutch barn, showed that one man could load, transport and unload 120 bales in 48 min (18 man min/ton) and so a target of 150 bales (3·3 tons) handled from field to barn by one man in an hour is not unrealistic.[14]

Therefore, future acceptable systems must balance output of the 6 handling stages of baling, grouping, loading to transport, transporting, off-loading from transport, and loading into store. This will be done by improvement of the handling rate of individual stages, and in particular by the further development of equipment which enables bales to be grouped automatically into unit loads which form a temporary weatherproof holding stage, and yet are an integral part of a complete handling system.

3.2 Half-length bales

Reduction of the length of bales to about 20 in. facilitates handling of single units, but the use of a thrower is needed to reduce output bottlenecks created by manual loading.[15]

Fully mechanised systems for off-loading at the barn are not readily available, but hand labour can operate at a rate of 10–12 tons/h by dragging the bales onto a cross conveyor, from which they are elevated and loaded to store, using a two-way knock-off board. Short bales have a tendency to roll backwards down an elevator set at an angle greater than 25°, and some form of cover, or a closed-in elevator, would be needed for steep angles. Storage capacity compared with hand stacking full size bales is reduced, but results have shown that reduction in bulk storage density, compared with bale unit density was 20·5% for hand stacked full size bales and only 24·3% for random stacked half length bales.[15]

Since the production of half length bales does not lend itself to an intermediate field conditioning stage, this system is best suited to use in conjunction with storage drying, which has been shown to be feasible at heights of up to 20 feet.

Shortening bale length causes some increase in the total length of twine required, but as thinner twine, especially poly-propylene is suitable, there is not an appreciable increase in cost. Even so, attempts in U.S.S.R. to produce small bales without the use of any twine is of interest[16] and in a limited study at NIAE a technique was developed in which stepped prongs, fitted to the face of a baler ram pushed plugs of hay from each charge into the previous charge.[17] Results obtained using a normal baler were not very satisfactory, because very high density plugs were formed within the bale, but it is possible that the system could have some merit if a baler with a longer ram stroke and chamber were to be used.

3.3 Large sized bales

Since many handling systems are based on the manual grouping of small bales into composite loads it is logical to produce a single unit load of a weight suited to tractor handling.

In a detailed study bales weighing from 1100 to 1990 lb, and measuring 6 ft × 4 ft × 5ft 6 in. were laboriously made in an experimental press and stacked in a field on pallets to obtain some accurate data on densities, drying rate and handling potential.[18] Density at baling was similar to standard bales and ranged from about 8–15 lb/ft^3 with moisture content varying from less than 20 per cent to over 35 per cent. Large bales heated more than equivalent stacks of small bales, but provided moisture content was less than 25 per cent and density as baled not greater than 8–10 lb/ft^3 good hay was made following an appropriate period of field conditioning. A bale of 132 ft^3 volume weighs 1100–1300 lb when suitable for storage. Production of bales at a moisture content of 30 per cent or higher, led to heating in the field up to nearly 150°F and even more important to a temperature of over 100°F for several days, resulting in unacceptable moulding.

Both experimental and on farm results have shown that for similar conditions of crop, large bales need more field time before they can be safely stored, and at higher levels of m.c. some form of artificial conditioning is required. This has proved to be possible and because all handling can be done from the tractor seat, batch drying either on a drive over platform or in a field tunnel is feasible.

Palletised bales were loaded experimentally to a trailer and off-loaded into a barn at a rate of about 60 bales or 30 tons an hour, and using a suitable size of trailer therefore it should be possible for one man to load, transport and unload large bales at a rate of over 5 tons/man h.

Future developments depend firstly on an evaluation of the system under farm conditions. Details of prototype field equipment are not at present available for publication, but experience of handling and drying obtained on a farm, where about 3,000 large bales were made in 1970, indicates the possible value of this complete system of handling which is shown at its best when operated by one man, who can achieve a high rate of work, even on hilly ground in small fields, using only baler, tractor mounted squeeze loader and trailer. A one man unit has cleared and stacked a 12 acre field of hay sited half a mile from the farmstead in 3½ h. Re-stacking within the farm building, for example removal from a batch drier or temporary out-of-door storage to final store, can be done at the rate of 10–15 tons/h.

Before this method could be generally acceptable there are a number of problems to solve. The most important of these is the production of a competitively priced large baler of suitable output, and development during the next two seasons will show whether a successful prototype can be translated into a commercial machine.

Although large bales make stable loads on trailers, provided that the bale height is less than either of the plan dimensions, they can be wasteful of space especially in old buildings; for optimum use it would therefore be necessary to use wide span or specially designed buildings. They are also less stable in the stack than small bales, because cross tying is not practicable, but self-standing stacks can be built up to 15 ft i.e. 3 bales high. Handling requires the use of medium powered tractors i.e. 60–70 hp fitted with heavy duty front tyres, power steering and rear ballast; the stresses on loader frames and mountings are likely to be high on uneven fields, although no more so than with many other present day unit load handling systems.

Given satisfactory equipment there can be little doubt about the potential value of large bales for handling. Whether or not they become a widely used future development will also depend on ancillary requirements such as the need to provide some form of artificial conditioning equipment or to add a preservative to maintain quality, and the acceptability of moving barrier easy-or-self-feed systems which differ in detail, if not in principle, from those used with normal bales

3.4 Hay wafering

Handling hay in cubes of 1¼ in. × 1¼ in. ×2 in. allows complete elimination of hand labour, and by increasing bulk density to 3 or 4 times that of bales simplifies both transport and storage problems. At present the only practicable field machines are made in America where they operate mainly in lucerne dried to 10 per cent m.c. or less, in arid zones such as California. Considerable experimental work has shown that the power consuming compressive extrusion methods of packaging hay are limited in scope because they are sensitive to moisture content and type of crop.

A principle similar to the rolled bale has therefore been devised as a means of producing wafers of high moisture content grass hay made in temperate climates. Experimental work in America and Germany during the past decade has shown the potential of this equipment, which uses 4 skewed rollers to produce a continuous stream of packaged hay about 2 in. dia with a unit density of 40 lb/ft^3 and bulk density of 25-30 lb/ft^3. There has also been parallel work to develop production machines in both countries. Details of experimental developments can be read elsewhere,[19, 20, 21] but a summary of the present position will help to determine the likelihood of this development being available as the dominant feature of a complete handling system within the next 10 years.

Work up to 1968 showed that there were serious problems in production arising from uneven feed rates when picking up from the swath. Very hard centres in the wafers led to rejection by the animals, and the wide variation in density over the cross sectional area made artificial ventilation in high m.c. wafers difficult, with the outside liable to break away as fines and the inside liable to mould.

Recent American developments show that most of the mechanical problems of feeding crop to the machine have been overcome and that the problem of internal hardness can be solved by giving the wafers a hollow centre. Good wafers were made from grass, and indications were that the upper limit of m.c. would be 40 per cent limited by machine efficiency, and the lower limit about 20 per cent, restricted because of fracturing of the stems and reduction of wafer quality.[22]

Any field machine will need a fines return to deliver chopped hay particles into the feed mechanism so that they can be wrapped into the wafers. Further work is needed on cutting the continuous hay core into wafers without causing damage to the surface resulting in a tendency for the outside layers to unwrap.

Implications of research under European conditions have been summarized by Professor Matthies.[23] A prototype field rig has been made in which the skew angle of the wafering rollers, controlled by the torque, is varied hydraulically, to compensate for irregularities in the swath and so to regulate wafer density. This appears to overcome the two main design problems in field work, of obtaining smooth flow of hay to the die and of producing a wafer of consistent quality.

It seems therefore that this system of hay handling has now been developed experimentally to the stage where most of the mechanical problems can be solved, and although no published data are available some commercial developments are believed to have reached the stage at which a production machine, using multiple dies, has already an output comparable with a baler for a power requirement of only 10–12 hp h/ton. The lack of a production machine, which would need to be made and sold in large quantities to be competitive, may well depend less on unsolved fundamental design problems than it does on lack of commercial incentive to produce an alternative to the pick-up baler.

3.5 Handling chopped hay

The handling of chopped hay differs from large bales and wafers as a possible alternative to conventional bales, because suitable equipment is already in use on many farms for silage making. Some fundamental operational points must be considered. Density of the product is affected both by the moisture content and chop length. There is a conflict between a very short length of ½–1 in. which increases trailer and storage capacity, and a longer chop length which ensures more even drying in the store. Output of individual harvesters of whatever type should be at least 4½ tons dry matter/h overall and this depends, as with silage making, on the provision of adequate power. Good maintenance of the chopper blade is essential to obtain an even and consistently short length with full chop machines.

System output is closely related to trailer size, transport speed, as affected by road conditions, and turn round times especially at the store. Measurements have shown that the dry matter capacity of the standard trailers normally used varies from under 5 to about 18 cwt, and only specially constructed trailers hold 1 ton or more.[24] A rate of loading to the farm of 6 tons/h (4 tons/h d.m.) using either blower or elevator can be achieved, but blowers have created dust problems, uneven distribution and dense patches in store in spite of the use of specially designed delivery nozzles and spreaders. Elevators, which use about one-eighth of the power for the same output, do not provide a ready answer to spreading, except by hand, and are often inconvenient to fit into existing buildings.

Much attention has therefore been paid in experimental work to the study of rapid methods of transfer of grass from trailer to elevator, and to mechanised means of spreading, using mechanical elevators and overhead conveyors. At the NIAE horizontal contra-rotating shafts, using two pairs of four tines operated at 85 r.p.m. laid a fairly even band of grass at right angles to a conveyor, which was moved backwards and forwards on a monorail to cover the whole drying bay [24]. Results of work at Reading University[25] in 1969 show that when using a nominal chop length of 2–3 in. hay with a m.c. of between 25 and 55 per cent was easily handled by an elevator, conveyor and tined spreader and a reasonably even spread was achieved. As storage height increased, to a maximum of 15½ ft, fan pressure became too high and an increase in chop length to 3–6 in. caused no handling difficulties and reduced the resistance so increasing airflow. Density of the dried hay was 280 ft^3/ton of dry matter and on this basis about 330 ft^3 must be allowed for a ton of hay stored at 15 per cent m.c. which compares with a figure of 320 ft^3/ton determined on a farm scale drier.[26]

Alternative methods of spreading based on an enclosed steep angled elevator and specially designed top conveyor has been studied at Newcastle University and results are reported elsewhere in the Conference.[27]

Some of the handling problems have arisen because standard buildings have been used and ideally chopped hay should be loaded into a round building. The use of hay towers, developed on the Continent, greatly facilitates both spreading in the drier and unloading from it. Examples of two basic types of installation have recently been erected in U.K. and preliminary technical results are interesting.

One type of unit consists of a circular roof and forming skirt which is lifted as the grass is blown in to build a round free standing stack up to 33 ft dia. The second type is a tower of similar diameter constructed of ventilated side panels, and both types are radially ventilated. Loading is based on the use of a blower and permanently installed spreader which can also be used to unload the hay for feeding. During 1970 hay for one installation, mown with a flail haymaker and flail chopped from the field at 35–45 per cent m.c. in 6–9 in. lengths, was handled by one man at a rate of about 10 tons dry hay daily.

For large scale application however, where the use of several trailers is required the benefit of having a method which offers mechanical handling of a free flowing material at all stages is partly offset by a low transport density of about 3 lb/ft^3; the system output, although acceptable in terms of man h/ton, is likely to be lower than for most bale handling methods whilst storage costs, with density ranging from 4–7 lb/ft^3, will be higher than for bales. These factors have played an important part, together with difficulties of elevation and spreading, in both retarding the acceptance of this method of handling and causing the system to be discontinued on some farms on which it has been used.

It may also be considered a disadvantage that because a field holding stage cannot be introduced into the system, artificial drying is essential under U.K. climatic conditions. However, for those who are prepared to wilt in the swath to 35–45 per cent m.c. the technique offers an opportunity of producing high quality hay entirely without the manual handling which has usually proved to be a handicap to other methods of barn hay drying. Chopping of hay is therefore likely to have a limited place in the future, and is particularly applicable where some silage is also made with similar machinery to cope with the flush growth of grass in May and June. The indications are nevertheless that those methods of handling in which the final product has a higher density, especially for feeding, are likely to be more widely accepted.

4. Improvement of hay quality

In spite of the use of improved mowing and swath conditioning methods, it is often difficult to reduce m.c. quickly to less than 30 per cent. Collection from the swath therefore often takes place at a too high m.c. for safe long term storage so limiting handling methods to those systems which allow a break in the process for further field conditioning unless alternative methods are found to prevent heating and moulding in store.

These methods fall into two main categories:—
(i) The removal of excess water by artificial ventilation
(ii) The use of additives to help control fungal development.

4.1 Barn hay drying

This process involves the removal of relatively small amounts of water per ton of dried product, ranging from about 0·25 tons when drying from 35 per cent m.c. to nearly double that amount when drying from 45 per cent m.c. Drying in store cannot be divorced from handling systems such as chopping, of which it must be an integral part, and the aim in this section is to discuss some points of general detail not covered in Section 3.

Work at research establishments and E.H.F.'s has shown that the final processing of hay within this moisture range is technically feasible and a small number of farms in the United Kingdom have shown that they can consistently produce a high quality feed using an appropriate drying system.

The reasons for limited acceptance of systems, for which adequate technical data are available for all practical purposes[28,29] appear to be capital cost, which can be justified in terms of improved recovery of dry matter, and problems of handling the crop into and out of the drier. These were certainly irksome when drying took place in small batch units, from which hay had to be removed to final store by hand, but can be largely overcome either by drying in store or by using a completely mechanized system of batch drying, in which all handling work is done from the tractor seat.

The most acceptable method of drying in the immediate future is likely to be based on a current mechanised system of bale handling, in conjunction with storage drying, to minimise man-handling.

In its most effective and costly form storage drying requires the use of a walled building with large loading doors, and a mesh or slatted floor over a fixed horizontally disposed plenum chamber; there are successful installations however with little or no side cladding. Ideally hay should be wilted to less than 40 per cent m.c. and bales loaded a few layers at a time to a maximum height of 18–20 feet. An airflow of between 8,000 and 15,000 ft^3/lb water removed is likely to be required, depending on heat input and the efficiency of air distribution; very much higher figures have been recorded in practice. Provision must be made for an airflow of about 45 ft^3 min^{-1}ft^2 of floor space against a pressure of 3 in. water gauge,[30] and if heat, which is not essential, is provided it should not be used to warm air by more than 10°F.

Little has been done to mechanise the handling of bales into and out of this type of drier, which lends itself to the use of half sized standard bales, very large bales and hay wafers, as already discussed.

4.2 Dutch system of drying

Capital costs of new buildings are kept low in Holland by using only supporting poles and a roof; ventilation with a 'bung unit' placed in the centre of the stack eliminates the cost of any type of side cladding. This method, which also leaves the building clear for other use for part of the year, has been adapted in the United Kingdom for bale drying in square stacks.

An airflow of 10 ft^3/min per bale at a pressure of 2·5 in. water gauge is required and fans have been used which vary from 5 hp delivering 8,000 ft^3/min for a 15 × 15 ft stack holding 800 bales (15 tons) up to 25 hp for a 30 × 30 ft stack which requires 30,000 ft^3/min and contains 3,000 bales (50 tons). Fans are installed so that they can be used for more than one stack in a season and this can be achieved either by mounting them on an overhead rail or by using an under-ground airduct to deliver air to the appropriate point.

4.3 Chopped hay drying

The same type of structure can be used for chopped hay drying, essential as a final stage of this method of handling. Chop length must be related to moisture content as both affect density which correlates closely with temperature rise in unventilated hay[31] and with static pressure in artificially dried hay. In the m.c. range of 35–45 per cent length can be as short as 2–3 in. and ideally it should not exceed 4–6 in. because this severely reduces storage capacity.[32]

Practical implications of both farm and experimental results, so far as they affect future likely developments, can be summarized as follows:—

(i) A chop length of about 2 in. at a m.c. of between 30 and 40 per cent should ideally be used as a suitable compromise between trailer and building capacity, pressure of the ventilating fan and ease of distribution of the drying air.
(ii) Design considerations must allow for up to 400 ft^3/ton of hay at 15 per cent m.c. and a greater amount if the chop is very long, compared with 350 ft^3/ton or less for barn dried bales.
(iii) Fan pressure can be reduced by placing unchopped or fairly long hay at the point of air entering to the crop.
(iv) It is especially important with leafy crops to avoid the build up of high pressure cones in the drier and in any case leafy crops pack more tightly than stemmy crops. With stemmy crops little difficulty is experienced in obtaining even drying but a drier should not be installed to deal with low quality hay.

Any method of barn drying however still requires a substantial amount of field wilting and alternatives have been sought which would allow economic drying of either direct cut or wilted chopped grass. A system in the early stages of commercial development, and proven on a small scale, consists of loading chopped grass to drying drums towed around the field. The drums, which contain from 9 cwt to 15 cwt of dry matter and from 2–3 tons of water, are directly connected one at a time to a batch drying unit; using air with a temperature rise of about 190°F from 35min to 1½ h are required to dry a batch depending on initial m.c. The dried product is then directly unloaded into a barn from which it can be easily fed. Output from this system, which can be regarded either as the production of very high quality hay, or of good quality dried grass, is about 3–4 tons of dry matter daily with unwilted crop of 80 per cent m.c. In mid summer, when wilting to 65–70 per cent m.c. should be possible, 5–6 tons can be dried daily, provided total haulage and unloading times respectively do not exceed 20 and 15 minutes.[33] Therefore it would be possible to produce from 300–400 tons in a 60–80 day working season.

The place of this technique in future will depend on its being developed to a high level of technical efficiency, which may include some form of packaging of the chopped grass, but even if technical and handling problems are adequately resolved, the capital investment required will restrict application to a farmer or a group of farmers with not less than 100–150 milking cows. Similarly, the future use of hay drying towers is likely to depend as much on economic as on technical considerations.

4.4 Use of additives

Additives, such as formic and propionic acid, have been successfully used to control fermentation in silage and to prevent the development of mould growth in moist grain. A number of experiments and farm trials have been carried out with partly dried hay and the results are discussed briefly because their successful application on a large scale would have an important bearing on practicable methods of handling in the future.

Chemical additives were first used to try to reduce the incidence of heating and moulding which leads to the growth of *Aspergillus fumigatus*, *Micro-polyspora faeni* and other potentially harmful fungi that produce toxic metabolites or spores which can cause 'Farmer's lung' in man and aspergillosis ulceration, abortion and general health disorders in cattle.[34]

Detailed studies, some using re-wetted hay, showed that under laboratory conditions 0·5–1 per cent propionic acid controlled moulding at m.c. of 30 and 50 per cent respectively, but formic acid at 1 per cent addition and the use of some proprietary additives failed to prevent moulding in the 30–40 per cent m.c. range. Later work indicated little or no lateral effect of inhibitors in damp hay and for an effective and economical method to be devised for field use uniformity of spread was vital even though this might require the use of water as a dilutent.[35]

Field trials carried out on Experimental Husbandry Farms[36] and by commercial organizations[37] over a 4-year period, used a range of additives, which included 'Hay Guard' and 'Hay Savor', applied by applicator, and propionic acid, formic acid, acetic-formic acid mixtures and formic propionic acid mixtures applied by jets discharging into the mouth of the baler; one case is reported of the acid being spread onto the crop during the final tedding but this required a very high application rate. Propionic acid alone showed real promise of controlling moulding and it was concluded that a 2–3 per cent application at a m.c. of 30 per cent would be required.

Clearly adequate mould control can be obtained by applying large amounts of acid to offset the effects of uneven distribution, but since 1–1½ per cent would cost from £1–£1·50 per ton dry hay, depending on moisture content at application, compared with a drier running cost of 25–60p the rate must be limited. It seems unlikely that the lowest successful rate used in a laboratory, in some cases on re-wetted hay, will achieve satisfactory field control, and an application of less than 2 per cent may prove to be unrealistic. All research and experimental results indicate that the main bar to progress of a technique which would enable hay to be collected from the swath at m.c.'s up to 35 per cent, and hauled directly to store, where it would keep without further conditioning, is the lack of an efficient method of application.

If such a technique can be satisfactorily developed, it has the great merit that it can be easily used within the framework of many present and projected handling systems. Results would be measured in terms of both improved quality and reduced labour costs because of the elimination of a required field conditioning stage, but it is not envisaged in the foreseeable future that the overall effects would be to reduce total cost and improve quality beyond the levels possible with well managed barn hay drying.

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Engineering Aspects of Green Crop Conservation

WORK ON CONSERVATION PROBLEMS AT THE UNIVERSITY OF NEWCASTLE-UPON-TYNE

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1. Introduction

In order to place the problems of grass conservation in perspective it is worth remembering how wide are the differences in methods of grassland management. At one end of the spectrum is the farmer who is primarily concerned with summer production from grassland by direct grazing. For him conservation is a by-product of grazing in that he regards it as a form of topping for his pastures to improve the efficiency of grazing, and only looks to the conserved material to provide some winter maintenance for part of his herd. At the other extreme, is the specialist dried grass producer who grows the crop to provide a grass meal of uniform composition. For him conservation must be predictable while the grass which he produces has to compete in price and quality with the whole range of processed feeds that are available to livestock producers. Between these two extremes the majority of farmers strive for a compromise between both summer production from grazing and winter production on conserved and processed feeds.

Obviously the process of grass conservation cannot be dissociated from the broader system of management of which it forms part and because there is no single system of grassland management, it is unlikely that there will be a single solution to the conservation problem. The variables are the acreage of grass to be harvested, the quality of the feed required and the amount of fertilizer to be applied. Some of the constraints are the size of the enterprize, availability of labour and capital, the point of utilization and the growth pattern of grass. The overall management objective is likely to be maximization of profit within the total enterprize.

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The growth pattern of grass is probably the biggest single constraint in a harvesting system. The rate of growth is at maximum during May, with the result that it is necessary to harvest large quantities within a short period of time especially if a high protein content is required. The organization of cutting, processing, transport and storage of several acres of grass within a period of about two weeks is a severe problem in itself. The growth curve of grass favours a conservation system which is able to meet peak demands, rather than one which is geared to a steady flow. From a materials handling point of view, hay and silage systems match the peak requirements of grass growth with simple machines of high capacity, which are within the organizing capacity of most farmers.

Regarding grass harvesting machinery purely from a materials handling point of view, there is considerable scope for improvement in regard to reliability, compatibility of the different machines in the chain and rate of working. However, materials handling is not the whole story; there is also the question of losses, reliability and point of utilization.

Grass is primarily a source of carbohydrate and protein. In comparison with cereals it is not a cheap source of carbohydrate, but as a source of protein, it is economical. From the survey of costs of milk production on northern farms it is possible to gauge the wide variety of feeds used by farmers and also to derive costs for both energy and protein (Table 1).

The cost of harvesting barley is relatively high in that farmers have adopted a system of minimum grain loss harvesting based on specialized machines which are only used for about 10 per cent of the year and which contain a high insurance element against poor weather conditions at

TABLE 1

Types and costs of feeds used on northern dairy farms*

Type of feed	No. of farms using	Energy value, Mcal/ KgDM	Cost per unit of energy, £/Mcal × 1000	Protein content, %	Cost per unit of protein, £/cwt	DM, %	Cost per unit DM, £/cwt
4 lb/gal cake	13	3·0	12·6	12·0	16·1	88	1·9
3·5 lb/gal cake	11	3·3	12·1	14·0	14·5	88	2·0
3 lb/gal cake	1	3·4	12·2	16·0	13·1	88	2·1
Balancer	11	3·4	14·0	17·0	14·2	88	2·4
Grazing nuts	8	3·0	12·4	7·2	26·2	88	1·9
Oil cake (H.P.)	5	3·4	13·9	40·0	6·0	88	2·4
Oil cake (L.P.)	2	2·9	9·5	25·0	5·7	88	1·4
Beet pulp	11	2·9	8·9	10·6	12·5	88	1·3
Flaked maize	9	3·7	8·7	9·9	16·7	88	1·7
Brewer's grains	7	2·6	5·6	12·0	6·1	34	0·7
Fish meal	3	2·9	25·7	55·0	6·9	88	3·8
Hay, top quality	12	2·2	3·6	5·0	8·1	85	0·4
Hay, medium quality	11	2·1	4·9	4·0	13·2	85	0·5
Silage, medium quality	6	2·4	5·7	13·0	8·5	20	0·6
Silage, low quality	1	2·2	7·6	7·5	14·1	20	0·8
Kale	8	2·9	4·9	12·0	6·0	14	7·2
Roots	16	3·0	7·8	7·0	17·0	11	1·2
Barley	21	3·1	4·6	6·8	10·5	86	0·7
Oats	8	2·9	4·9	8·0	8·9	86	0·7

*Survey of 23 farms carried out by Agricultural Economics Department and analysed by Department of Agricultural Engineering, University of Newcastle.

the time of harvest. Possibly one way of reducing harvesting costs for cereals is to tolerate a higher grain loss while at the same time reducing the overall system costs by increasing the load factor of combine harvesters.

Losses in the harvesting of grass do not seem to be regarded as an important element in the system and in most cases are secondary to such considerations as capital investment, problems of organization and materials handling. All systems of grass conservation involve losses of nutrients, which of course can be compensated, if necessary, by supplementation at feeding. One reason for field wilting is to off-set the effects of losses because by reducing the moisture content of the conserved grass, the concentration of nutrients in the material which is fed to cattle is at least sufficient to prevent intake becoming a limiting factor for the animal.

Once field wilting becomes a necessary element in the conservation process, harvesting of grass becomes unpredictable in so far as field wilting is dependent on weather conditions. This fact leads to several possible strategies in relation to conservation systems:—

(i) elimination of the field wilting process by using either grass drying or direct cut silage. Either of these methods allows the time of cutting to be selected independently of the weather conditions. Drying is capable of producing a highly concentrated forage with low losses of nutrients. Ensilage of high moisture grass produces a feed of lower value than the original grass because of losses and with a high risk of poor fermentation. While dried grass can be processed into a form for transport over long distances, silage must be used close to the point at which the grass is grown;

(ii) partial wilting in the field and final conservation by ensilage or barn hay drying. The time of cutting is restricted by the prospects for field drying. Obviously the shorter the period of field wilting the better the chances of completing it. The time spent in the field depends on the weather, the amount of wilting required and the rate of drying, which can be influenced by machinery;

(iii) complete drying in the field which is the traditional method and the one which is most widely practised. This method is the one over which the farmer has least control in regard to final quality and the amount of losses which take place.

From this brief review it is clear that only high temperature grass drying offers a conservation system by which it is possible to make the grass harvest independent of the weather and produce a feed of predictable quality. Our studies at Newcastle are concerned with the organization and equipment of high temperature grass drying in order to improve its economic effectiveness. The work can be summarized under three headings:—

(i) the organization of a conventional high temperature grass drying unit;
(ii) a laboratory study of the processes of grass drying and its application in the design of new dryers;
(iii) combinations of wilting and barn hay drying.

2. Organisation of a Grass Drying Unit

A simple but realistic problem is to study the allocation of resources on a farm which produces grass for drying at a single plant and where the total output from the dryer is sold off the farm. Under those conditions the sale price of the dried product is determined by its protein content.

The variables associated with grass production are:—
(1) the acreage of land on which grass may be grown;
(2) the quantity of nitrogen which is applied to the grass;
(3) the stage of maturity at which the grass is cut.

Increasing the rate of application of nitrogen and the length of the period between cuttings increases the yield of dry matter per acre. However, the protein content of the grasses decreases with maturity. As the sale price depends on both quantity and protein content, there is an optimum time for cutting in relation to profitability.

A constraint inherent in grass production is the growth pattern of grass, which reaches a pronounced peak in the period May–June. A major problem of organization is to match such irregular production with the needs of a dryer which are regular.

The linear programming model proposed by O'Donoghue[1] deals with the problem of grass production by treating it on the basis of acreage and nitrogen variables: viz. there is a basic grass production per acre without any nitrogen and additional production in relation to nitrogen application can be superimposed on this basic yield. The question of finding a suitable interval between cuttings is examined by dividing the growing season into a series of consecutive time intervals of 2 weeks duration. If grass is cut in sector S during time interval t, then grass of 4 weeks maturity can be cut from that block at time t + 2 or of 6 weeks at time t + 3, as the time interval is 2 weeks being the lowest common multiple of the chosen periods between cuttings. Four and six week cutting intervals were chosen for this model because these are of most interest in practice and the resulting time interval of 2 weeks tends to dampen day to day variations and give a model of reasonable size. A constraint on the acreage used in the model is that available for grass production, but is also related to the first cuts taken and to the barley acreage.

It is represented by the equation

$$O = A_{t+2,4,s} + A_{t+3,6,s} - \Sigma_m A_{t,m,s} \qquad (1)$$

where $A_{t,m,s}$ = acreage of grass cut in time period t, of maturity m, on sector S.
- t = a time period of 2 weeks duration (for t = 1, 2, 3, 4...equal to 2, 4, 6, 8 weeks of the season).
- m = maturity at cutting (m = 4, 6, for a 4 week or 6 week cutting).
- s = sector of farm in which cutting takes place, in cases where it is necessary to distinguish between them.

The amounts of dried grass produced at different levels of protein are represented by categorizing crude protein contents at different levels, viz. 12–14; 14–16; 16–18; 18–20 per cent. Balancing the quantities of grass harvested in each protein category by the quantities sold:

$$O = \sum_{i=1}^{n} YA_{i,p}\cdot A_{i,p} + \sum_{i=1}^{n} YN_{i,p}\cdot N_{i,p} - GS_p \qquad (2)$$

where i = an index to represent a cut taken in any time period of any maturity, whose protein content lies in the range specified by index p.
- p = 1, 2, 3, 4, for crude protein contents 12–14; 14–16; 16–18; 18–20 per cent.
- $YA_{i,p}$ = yield of grass per acre with zero nitrogen application having a protein level p (cwt grass/acre at 11 per cent m.c.).
- $A_{i,p}$ = acreage of grass cut (subject to i, p) (acres).
- $N_{i,p}$ = total nitrogen applied to that acreage $A_{i,p}$ subject to i, p (cwts).
- $YN_{i,p}$ = additional yield of grass per unit of nitrogen (cwt/unit N).
- GS_p = sales of dried grass in the protein range p (cwt).

The dryer can be regarded as having a constant evaporative capacity. Output on an hourly or daily basis will therefore vary with the initial moisture content of the grass but over a period of as long as 2 weeks the fluctuations will be damped out. The capacity of the dryer is a constraint which can be related to grass production by the equation:

$$b_t = \sum_{m}\sum_{s} YA_{t,m,s} \times C \times A_{t,m,s} + \sum_{m}\sum_{s} YN_{t,m,s} \times C \times N_{t,m,s} + DS_t \qquad (3)$$

where b_t = no. of drying hours available in time period t.

C = production rate of the drier; or the time to produce 1 cwt of material at 11 per cent m.c. (hours/cwt).

$YA_{t,m,s}$ = yield of grass at 11 per cent M.C.W.B. in cwts/acre from a cwt in time period t, of grass of m weeks maturity on sector S, receiving no nitrogen.

$A_{t,m,s}$ = acreage of grass of maturity m cut on sector S in time period t.

$YN_{t,m,s}$ = additional yield of grass of 11 per cent m.c. in cwts grass/cwt nitrogen applied.

$N_{t,m,s}$ = total nitrogen applied to $A_{t,m,s}$ in time period t on grass cut at maturity m, on sector S (cwts).

DS_t = slack or unused drier time in period t.

Grass cutting and transporting from the field to the dryer involves two principal operations, either of which may become the limiting factor in the organization of grass harvesting. When grass is being cut from fields near the dryer, the field capacity of the cutter is likely to be the limiting factor. As the distance from the fields to the dryer becomes greater, transport may become the limiting factor. The capacity of the field harvesting and transport system is related to production in Eq. 4 in which the time of working is related to area in the sectors near the dryer and to tonnage in the sectors remote from the dryer.

$$f_t = \sum_{\substack{m \\ s=\text{near}}} FT_{t,m,s} \times A_{t,m,s} + \sum_{\substack{m \\ s=\text{remote}}} FA_{t,m,s} \times A_{t,m,s} + \sum_{\substack{m \\ s=\text{remote}}} FN_{t,m,s} + N_{t,m,s} + FS_t \qquad (4)$$

where f_t = total field machinery time available in time period.

$FT_{t,m,s}$ = time taken for harvester to cut one acre in time period t on 'near' sectors only (hours).

$FA_{t,m,s} = YA_{t,m,s} \times ts$.

$FN_{t,m,s} = YN_{t,m,s} \times ts$.

ts = time taken to transport 1 cwt of 11 per cent m.c. material from sector S to the dryer.

FS_t = slack machinery time in period t.

By using cost coefficients for the different activities the model was used to define an economic objective function in terms of the total cost for the production system. The model was optimized using the technique of linear programming. In the general case the conclusions from a linear programming model are of a strategic kind. In order to use the model as an effective advisory tool, it is necessary to feed into the programme the real data of the particular production situation being studied.

The main but obvious conclusions are:—

(i) By agricultural standards, grass drying is a capital intensive enterprise. Fixed costs per ton of grass sold can make the activity uneconomic unless a high annual throughput is achieved. Direct costs are approaching £15 per ton of dried grass produced. Fixed costs/ton are a hyperbolic function of output. It requires a high load factor to keep fixed costs down to £10 per ton. However, with good management, a return of 20 per cent on capital employed is possible.

(ii) High applications of nitrogen at least up to the limit of the linear response in yield are recommended.

(iii) Profit on sales is closely related to the protein content of the dried grass. Grass of a crude protein content lower than 16 per cent is of marginal value.

(iv) It is recommended by the model that the interval between cuts should be 4 weeks except at the very end of the growing season when it can be lengthened to 6 weeks.

(v) It is usually uneconomic to select a dryer of sufficient capacity to deal with the peak of grass growth. Grass which grows beyond the dryer at that time should be made into hay or silage.

(vi) Good reliability of field machinery is very important in grass drying because of the high penalty incurred through loss of production from the dryer.

3. The Grass Drying Process

With the aid of a grant from the Agricultural Research Council we were able to carry out a laboratory investigation into the mechanism of drying grass. The purpose of the investigation was to provide data for the assessment of performance in existing dryers and to propose a quantitative basis for the design of new grass dryers. The work was carried out mainly by Menzies[2] who conducted over 500 experimental runs in the temperature range 11–418°C.

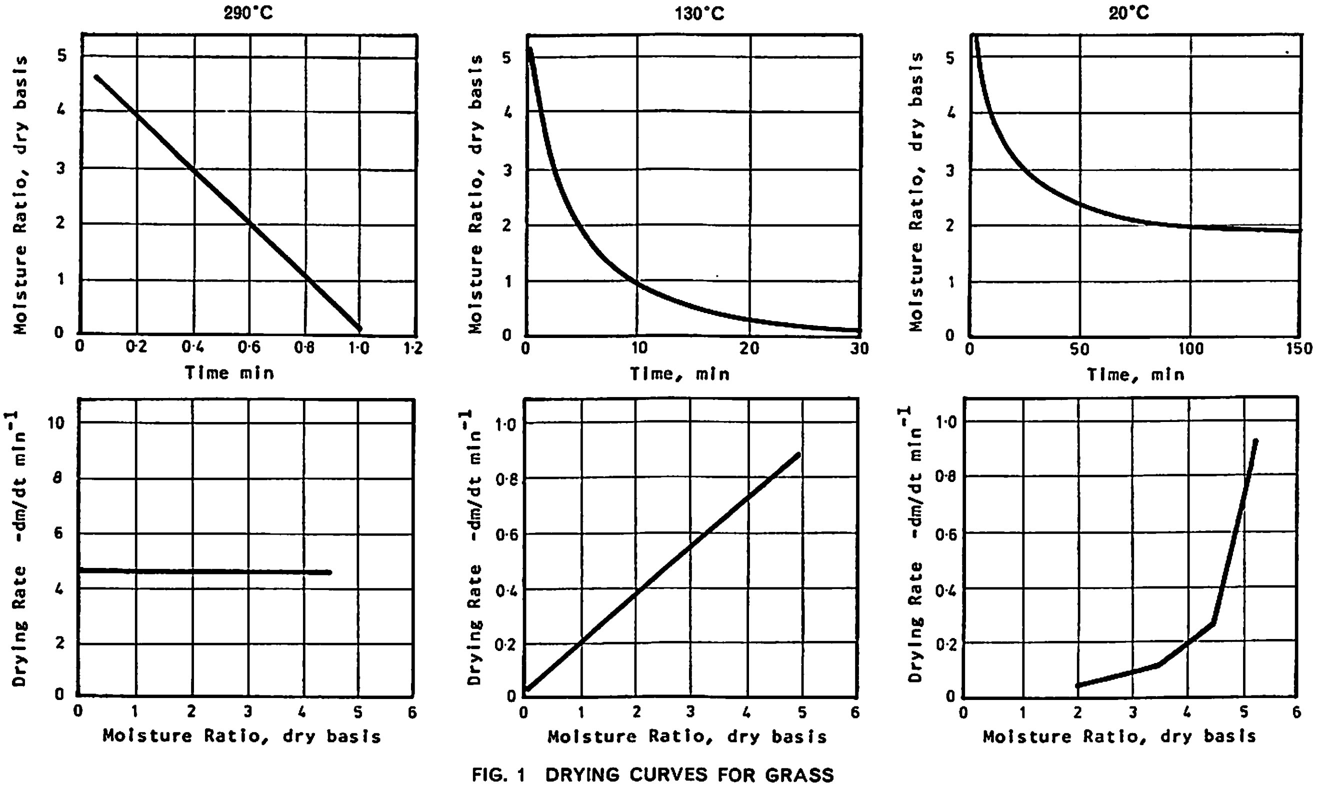

FIG. 1 DRYING CURVES FOR GRASS

The experimental technique used was to dry a thin layer of freshly cut grass in a stream of air at constant temperature and velocity. The weight of the grass was measured at intervals and results were transferred to a data-logger during drying. Test runs took from 6 seconds to 2 hours and the number of readings varied from 26 to 1000 during each run. From the weights a drying curve was found. The curve was differentiated to give the rate of drying. Typical drying curves are shown in Fig. 1.

Three different categories of drying were observed:—

(i) At temperatures above 200°C, the rate of drying remained constant at a particular temperature as the moisture content fell from that of the fresh grass (over 80 per cent wet basis) to a dry condition (under 20 per cent wet basis). Evaporation of moisture from grass under these conditions is analogous to that from a free water surface. The high rate of drying was attributed to the considerable alterations produced at the surface of the grass by high temperatures which melted the cuticular waxes.

At temperatures over 200°C the rate of drying $-\frac{dm}{dt} = k_o$.

Rate of drying increased linearly with temperature

$k_o = K_a + K_b T_a$

where $K_a = -1{\cdot}84$

$K_b = 0{\cdot}024$

$T_a = °C$

$k_o = \text{min}^{-1}$

(ii) At temperatures in the range 80–200°C, the drying rate decreased as the moisture content of the sample being dried fell. The rate of drying was found to be directly proportional to the moisture content in excess of the equilibrium moisture content (m_e)

$$-\frac{dm}{dt} = k\,(m - m_e).$$

The rate constant k increased exponentially with temperature

$$k = K_c \exp K_d T_a$$

where $K_c = K_d = 0{\cdot}02$.

The equilibrium moisture content depends on both the temperature and humidity of the air.

(iii) At temperatures less than 80°C, the drying curves were found to contain up to three distinct periods of drying, all of a falling rate character but indicating that moisture became increasingly difficult to remove from the plant as it dried, viz.

Stage 1: $-\frac{dm}{dt} = k_1\,(m - m_{e1})$

where $k_1 = 0{\cdot}031 \exp 0{\cdot}024\, T_a$

Stage 2: $-\frac{dm}{dt} = k_2\,(m - m_{e2})$

where $k_2 = 0{\cdot}008 \exp 0{\cdot}037\, T_a$

Stage 3: $-\frac{dm}{dt} = k_3\,(m - m_{e3})$

where $k_3 = 0{\cdot}003 \exp 0{\cdot}046\, T_a$.

One possible explanation for the three stages in drying at low temperatures is that there is no thermal damage to the plant. The first falling rate corresponds to the removal of readily available moisture in the intercellular spaces near the surface. The two other stages correspond to the removal of the more tightly bound water within the plant.

4. Effects of Physical Properties of Grass

It was found that drying rate for grass decreased as the grass matured. This could not wholly be described in terms of the change in the leaf/stem ratio of the grass as it grows. In some tests, leaves were removed from stems and dried separately. The leaves dried twice as quickly as the stem and perennial ryegrass dried about twice as quickly as Italian ryegrass.

No change in the drying rate was observed when the chop length of the grass was varied from 1–4 in. On the basis of a diffusion process of moisture transport within the grass, no significant improvement in drying rate could be expected from chopping until length/diameter ratio of the pieces of grass approached 1. The machinery of some dryers requires a short chop length on operational grounds.

5. Simulation of Full Scale Dryers

A method of simulating the performance of full scale grass dryers on the basis of laboratory measurements on thin layers has been proposed and verified.[3] It is based on a computer calculation of conditions in the dryer, which is regarded as an assembly of thin layers, during the transient stage between starting up the dryer and attaining steady state conditions. Initial conditions for the grass and air entering the dryer are known. The changes in conditions which take place in the dryer can be calculated from four independent equations:—

(i) the drying rate equation—in a grass dryer operating at temperatures higher than 200°C $-\frac{dm}{dt} = k$.

In an interval of time Δt the moisture of a layer changes by an amount $\Delta m = -k\Delta t$;

(ii) the mass balance equation—taking a mass balance for the moisture about a layer over a time Δt moisture lost by grass = moisture gained by air

$$A\Delta Z p_d\,(\Delta m) = AG\Delta t\,(w^1_a - wa)$$

$$\Delta w_a = w^1 - w_a = \frac{p_d \Delta Z}{G\Delta t} = \Delta m$$

(iii) the heat balance equation—taking a heat balance about a layer over a time Δt

energy lost by air = energy gained by material

$$AG\Delta t\,\Delta h = Ap_d\,\Delta Z\,|(C_p + m^1)\,(T^1_g - T_g) + \Delta m\,(T_g{}^1)|$$

(iv) the heat transfer equation—heat which is transferred from the air to the grass is used to raise the temperature of the grass, evaporate the moisture which is removed and raise the vapour to the temperature of the air leaving the layer

$$h_c\, a_s\, A\Delta Z\, \Delta t\, (T_a - T_g)$$
$$= A\Delta Z p_d\,|(C_p + m^1)\,(T_g{}^1 - T_g) + \Delta m\,(E - T_g)|$$

Drying in the first layer is calculated from the initial conditions of the air and grass. Using the above equations, the air conditions leaving the first layer may be calculated and these become the inlet conditions to the second layer. Computations are continued in this way until a loop is completed and conditions in the bed of grass at the end of the first time interval have been found. Further iterations are carried out and the progress of drying is computed.

6. Simulation of a High Temperature Rotary Grass Dryer

The high temperature triple pass rotary grass dryer, presented by Shell Mex–B.P. to the University of Newcastle upon Tyne, provided an opportunity to test the validity of simulating a complex grass drying situation. The dryer is a co-flow type in which the bed of solids is in a very expanded condition. The velocity with which the solid moves through the dryer depends partly on the cascading action of the rotation of the drum and partly on the pneumatic conveying effect of the air on the particles of grass as they fall through the drum.

The residence time of a particle in the dryer can be calculated by considering the time it spends cascading across the drum and the distance it is conveyed before it reaches the bottom of the drum.

Actual residence times for the dryer at Cockle Park were measured by Stuart,[4] who treated grass with a radioactive tracer. He fed the grass into the dryer in a batch and sampled its arrival in the dryer exit duct. The distribution of residence times in the dryer is shown in Fig. 2. He also measured the temperature profile along the length of the dryer and confirmed that the temperature fell quickly in the first pass near the grass inlet. There was only a small temperature drop in the other two passes. Simulated and actual temperature profiles are compared in Fig. 3. Simulated moisture content profiles are shown in Fig. 4. Further simulations were carried out in order to get a better understanding of the interactions between feed rate, temperature, residence time and final moisture content as shown in Fig. 5. An increase in the air temperature led to a reduction in the final moisture content in all cases. It also led to a reduction in residence time. At a grass feed rate of 14 lb dry matter/min. there was not sufficient drying capacity to reduce the moisture content sufficiently for storage.

The final moisture content of the grass is plotted against the exhaust air temperature in Fig. 6. The feed rate of the grass varies along each curve. It can be seen that in the range of inlet air temperatures used, this parameter had a negligible effect on the inter-dependency of m_f and T_f, which makes exhaust temperature monitoring a very suitable method of controlling the feed rate to maintain the moisture content of the dried product at a selected value.

There are economic limitations on the use of high temperature grass dryers at the present time which are being met by the scale of utilization. A rough guide to the load factor that is necessary is that a grass dryer capable of producing 1 ton dried grass per hour needs to produce in excess of 1000 tons dried grass per annum to be viable. Even at this level of production, fixed costs, mainly

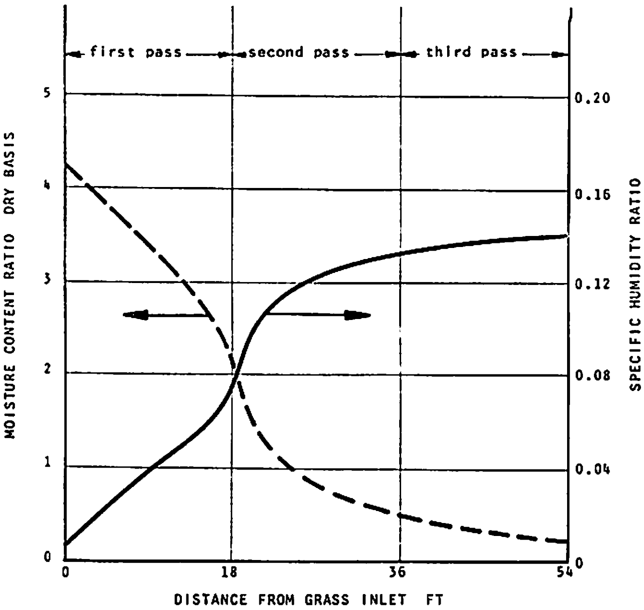

FIG 4. SIMULATED MOISTURE PROFILE, ROTARY DRIER

depreciation, account for 20 per cent of production cost by comparison with fuel 30 per cent, labour 25 per cent, fertilizer 15 per cent and rent, repairs, etc. 10 per cent.

When grass drying is carried out on a commercial scale there is no doubt that the enterprise can be very profitable. Under present conditions there are opportunities for specialist grass producers processing grass as a cash crop for sale in pellet or meal form. Such producers can be matched by specialist livestock units who buy in a large part of their nutrient needs.

Where grass is to be dried for consumption within the farm, the possibilities for reaching an economic load factor are

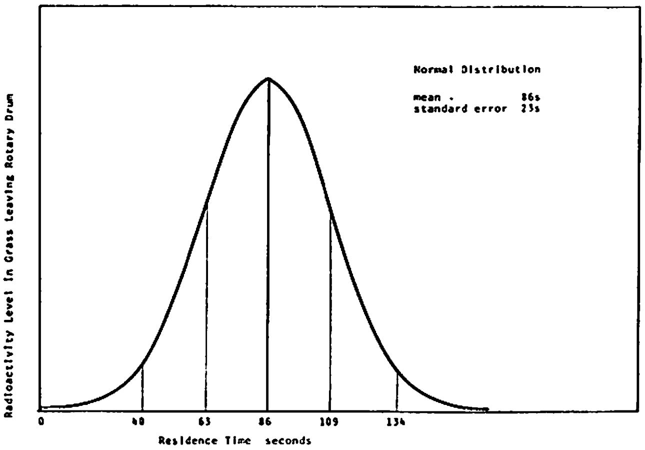

FIG 2. DISTRIBUTION OF RESIDENCE TIME, ROTARY DRIER

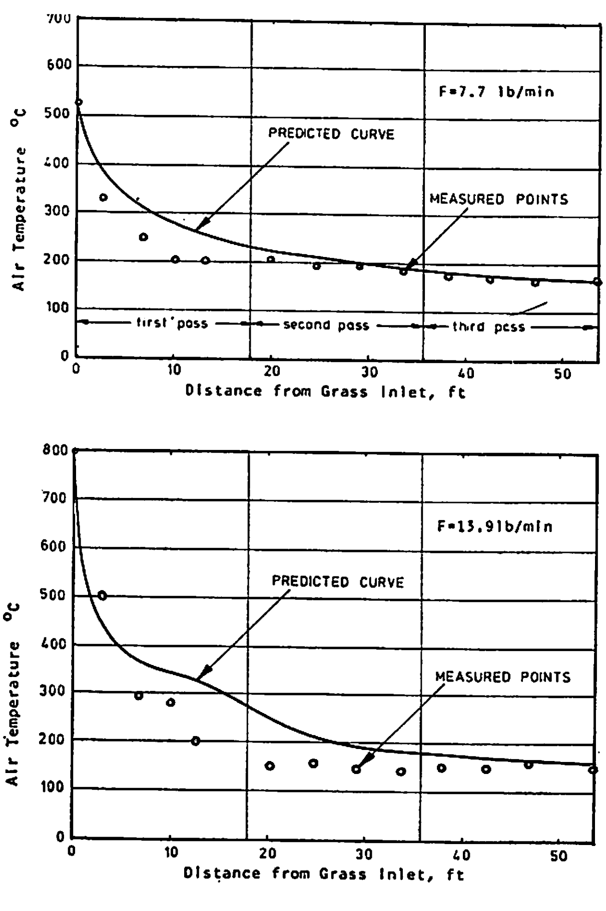

Fig 3. SIMULATED AND ACTUAL TEMPERATURE PROFILES, ROTARY DRIER

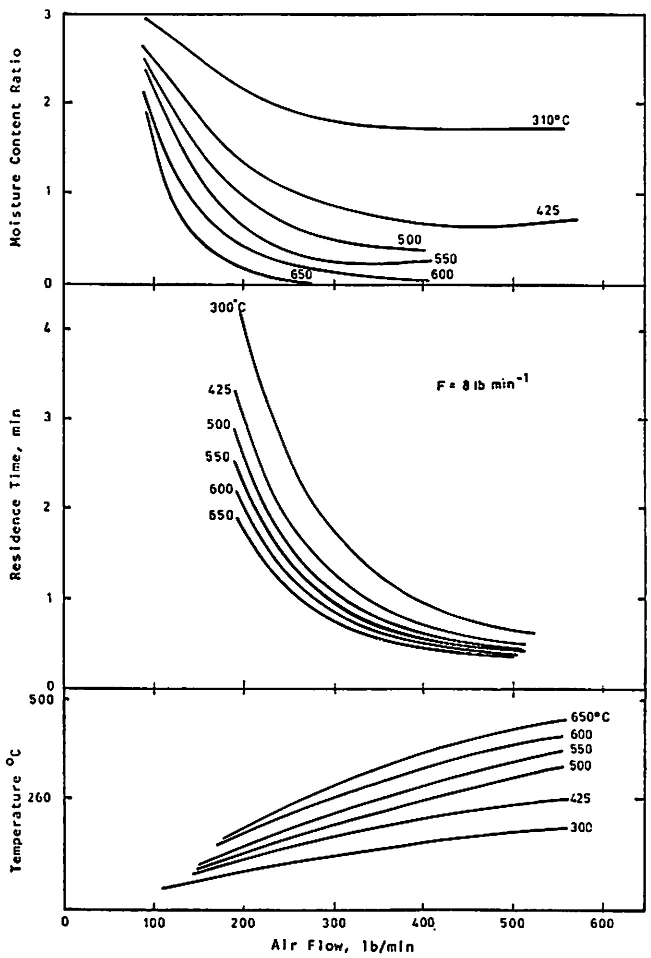

Fig. 5 PREDICTED RELATIONSHIPS OF MOISTURE CONTENT, RESIDENCE TIME AND FINAL TEMPERATURE TO MASS FLOW RATE OF AIR, ROTARY DRIER

not good, especially as barley-grass diets are cheaper than grass alone. The requirements of dried grass per dairy cow are approximately 1 ton per winter. We are examining three paths towards improving the economics of the small on-farm grass dryer:—

(i) Low capital methods of grass packaging which would help to reduce the fixed charges on the system. Large size plastic bags have been used during two seasons. They are capable of holding up to 300 lb which can be compressed to a density of about 7 lb/ft^3 by evacuating the air from the bag. In its present form, the labour required for handling and stacking the bags is too great. Work on packaging is being continued during the coming season.

(ii) Redesign of the grass dryer in order to reduce it to a size more closely related to the amount of grass it contains. The measurements of residence time in a rotary dryer showed that it contained only about 30 lb of dry matter, yet there are three concentric drums 18 ft long with an outside diameter of 7 ft.

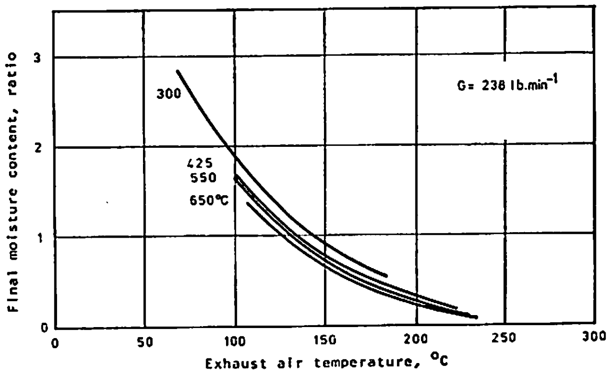

Fig. 6. FINAL MOISTURE CONTENT AS A FUNCTION OF EXHAUST AIR TEMPERATURE

(iii) Develop a storage type of barn hay dryer which would be low in capital cost, dispense with the need for packaging and reduce fuel charges by exploiting field wilting.

7. Barn Hay Drying

Barn hay drying has been offered as a way of improving the reliability of hay making by shortening wilting time in the field. With a barn hay dryer the farmer can respond to changes in weather by taking hay to the dryer at moisture contents up to 50 per cent. Obviously a barn hay dryer has a restricted capacity for drying and, to this extent, has the same inflexible response to the growth pattern of grass as a high temperature grass dryer. Since drying is carried out at low temperatures the processes of respiration are significant. It is difficult to obtain uniform air flow through a bed of hay; being a fibrous material, the resistance to air flow changes with the density of the bed. Once differential flow is established the effect becomes cumulative as drying reduces the resistance to air flow.

The barn hay dryer which has been built at Cockle Park is an attempt to form a bed of uniform density in which it is possible to get even airflow and control the drying process. As a result the thermodynamic efficiency of the dryer is high and losses due to respiration are reduced. The dryer is part of a one man haymaking system combining handling, drying, storage and easy feeding.

Grass for the dryer is cut and wilted using conventional haymaking machinery. When field wilting has been completed, the hay is picked up by a loader wagon. At the dryer the hay is unloaded into an elevator which transports it to the top of the dryer where the grass is fed on to the longitudinal conveyor which runs the length of the barn at eaves level.

The dryer is a conventional dutch barn in which the hay is placed on a weldmesh floor. Three sides of the barn are sheeted with Masonite on fixed purlins. The fourth side is a sheeted movable wall which can be moved outwards during feeding to the cattle which are kept in a lean-to beside the barn.

Grass from the longitudinal conveyor is ploughed on to a cross conveyor which carries it across the barn until it meets a reciprocating plough. The whole cross conveyor is slowly traversing up and down the length of the barn. The reciprocating plough gives an even spread across the width of the barn. The traverse speed is set so that each load is spread in about four layers which averages out the variations in moisture content and grass flow. Slightly heated air dries the grass evenly in layers from the bottom upwards.

The unit at Cockle Park has an evaporative capacity of 25–30 cwt water per day (i.e. it will dry 3 tons per day from 50 per cent; 4½ tons from 40 per cent and 10 tons from 30 per cent moisture content). If more heat is added, higher throughputs are possible.

It is built from two bays of a steel portal frame dutch barn 15 ft × 24 ft × 22 ft and holds 25 tons of hay. The loader-wagon is made by Bucher and the blower is a Lister M.E.U. A new form of light conveyor using polypropylene cloth has been developed and patented by Dr Wood; the University received a grant from N.R.D.C. to assist the development. The dryer was filled by the conveyor during the 1970 season. The unloading time for a trailer carrying 1½ tons was 20 min. The moisture content of the grass varied between 36 and 55 per cent during different fillings. Uniform drying was obtained. A comparison of hand filling and conveyor spreading based on the moisture contents of samples taken from the surface during drying in 1968 and 1970 is shown in Fig. 7. Uniform spreading shortened the drying time and gave more even drying.

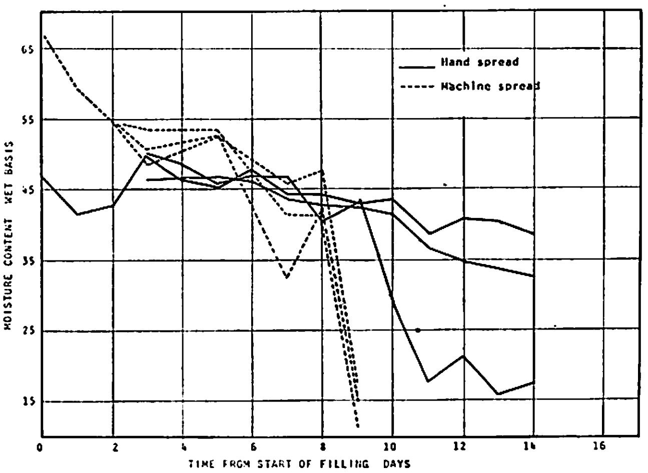

Fig. 7. EFFECT OF UNIFORM SPREADING ON DRYING RATE

Laboratory measurements of the rate of respiration of wilted grass under controlled conditions of temperature, humidity and grass moisture content, were carried out by Wood and Parker[5]; during 1970. They found that respiration rate increased directly with moisture content and that it was practically independent of temperature in the range 25°C–45°C. This was in agreement with the results of other workers who have also reported that at temperatures below 25°C, with falling moisture content, the rate of respiration fell as the temperature was reduced. These measurements confirm that respiration is a source of serious loss when drying is prolonged in a barn hay dryer.

8. Conclusions

Grass is a crop which has potential for high yields of both dry matter and protein, with a good response to nitrogen. Costs of production at the point of cutting are lower than for barley. However, because of its high moisture content, grass requires wilting largely in order to concentrate the nutrients and to compensate for losses during conservation.

.... *please turn to page iii of cover*

Engineering Aspects of Green Crop Conservation

ECONOMIC AND MANAGEMENT ASPECTS OF HAYMAKING, ENSILAGE AND GRASS DRYING

by H. A. THOMAS MS(Agric Econ), BSc*

Presented at the Annual Conference of the Institution of Agricultural Engineers at the Institution of Mechanical Engineers, London, on 6 May 1971

1. Introduction

18 million acres of grassland provide two thirds of the total feed requirements of cattle and sheep and approximately 4½ million acres are conserved annually in England and Wales as hay, silage, or dried grass. In spite of the vagaries of the weather and advice from the Welsh Plant Breeding Station, GRI, NIAE, NAAS, machinery and fertilizer firms, 75 per cent of this conserved output is in the form of hay. Many reasons have been advanced why, in spite of attempts to persuade farmers to change their method of conserving fodder, haymaking remains the dominant method of conservation.

The key to success in conservation lies not in the technique *per se* but in matching the system to the capability and interest of the individual farmer. Research and development work has highlighted the important areas, i.e. improving the quality of the product to be conserved and reducing the losses in field and in store. Previous speakers have referred to the need to optimise the system of mechanisation, feeding and housing, to achieve these ends. Until the optimum physical levels of production are achieved there is little point in applying economic yard sticks. Most of the surveys that have been conducted produce average cost data and in many cases there has been little attempt to match the physical and economic data or to define the farming system, and system of conservation adopted, or to identify the effect of the constraints of capital, labour and machinery. In some surveys attempts have been made to assess the management ability of the individual producer. Factors such as size and degree of specialisation of a particular enterprise will influence the economic performances achieved.

The way in which economic data are presented must be clearly understood and the basis of calculating any data should be specified. All of you will have been in conferences where different speakers have used different bases to calculate the capital costs. Some speakers will charge interest on the total amount of capital, others will charge it on half the amount; tax allowances may be included or excluded and different rates of cost of capital may be included in the calculations. All of these factors will influence the cost per ton, which will increase if, for example tower silos are filled to only 80 per cent of the manufacturers recommended capacity level. Underlying all or most of the analysis there is a subjective assessment on the part of the physical scientists or the 'instant' economists. We all oppose dogma unless it is our own dogma. These subjective judgements have caused apparently conflicting headlines to appear in the national press, e.g. 'NAAS recommends tower silos' in one conference followed by 'NAAS condemns tower silos' in another. Both statements could be correct for farmers or groups of farmers in areas with different systems, levels of management, and differing managerial skill.

In retrospect it is unfortunate that many people in research and advisory work did not follow the guide lines given by your president in his article in the NAAS Quarterly Review in autumn 1962.[1] In this article he took a specific size of herd, i.e. 60 cows, and calculated the capital cost for different types of silos and methods of feeding indicating the possible additional returns that may be achieved. The annual charge was calculated by taking the capital cost, ignoring the possible tax allowances and obtaining an annual amortisation charge. The returns were calculated in terms of a reduction in forage acres which was achieved firstly by reducing the dry matter losses in the field and in store and secondly by saving concentrates. There was a further saving by direct substitution for a lower cost per ton of feed. The benefit that could be obtained from using the forage acres saved depended upon the alternative use or opportunity value to which this land could be put.

The NAAS Farm Management Committee in the East Midland Region developed this type of approach to the economics of tower silos and mechanised feeding. In 1965/66 and 1966/67 a survey was undertaken of the farms in the Region which had installed tower silos. The data were analysed along the lines suggested by Culpin. An assessment was made of the three main factors:—

(*a*) capital costs and annual charges;

(*b*) returns from saved acres; and

(*c*) use of labour released from feeding.

It was clearly shown that the advantages expected from the introduction of a tower silo system were not automatically achieved and the record of performances emphasised the importance of all aspects of grassland and livestock management in whatever method of conservation and feeding system is adopted.

A similar survey was undertaken by V. H. Beynon and C. A. Godsall in 1965/66.[2] In their summary they confirmed that 'as with all the grassland systems complete success is not possible unless every aspect of the process of growing grass in the field, till this final utilisation in livestock production, is carefully scrutinised. In the entire process from growing grass for feeding stock it has been found that the technical ability of the farmers to supervise, adjust, and maintain the equipment is of paramount importance.' Only when the farmer has the ability as well as the 'know-how' should a change to a potentially more economic conservation system be recommended.

The group or mass approach to grassland management has undoubtedly done much to create confusion amongst farmers and experts by the conflicting subjective assessments that have too often been made. The management factor in applying new technology and investing additional capital resources have not in all cases been adequately assessed. There is a need for more precision and selectivity in giving individual advice to farmers. It is possible with the new ADAS organization to adopt a more catholic approach in sifting the results of independent and commercial research and development work. Only farmers who are capable of applying a new technology are likely to obtain the benefits that have been achieved under experimental conditions.

The farm management group in the NAAS have endeavoured to standardize the approach to capital investment appraisal and are continually stressing the need for a feasibility study before investing new capital, particularly in additional buildings and in the provision of new plant and machinery. The range of likely returns and costs needs to be appraised. The level of management in individual cases will determine the level at which the returns should be assessed. The framework of analysis must be undertaken against the whole farm background. Alternative uses of capital should be considered as well as the actual cost of capital. The return on capital provides the information on worthwhileness but in many cases it is also advisable to undertake a feasibility study as to whether the business can service and repay the additional capital within the life of a particular investment. Before a final decision is made information is required from the balance sheet as well as from the farm trading account. There is a need to

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know whether or not there is a deficit or surplus of cash from existing borrowing and under what terms additional capital can be borrowed and repaid at the different levels of taxation which may apply.

It is relatively simple to obtain the annual charge for given capital cost investment. With labour and machinery costs increasing if machinery has to be replaced within the term of years on which the calculation is based, there is a need to increase the replacement cost of machinery. While the pay-back or return on capital in simple interest terms may give a crude assessment, more precision is required in estimating the cash flow and to use the discounted cash flow method in order to calculate the internal rate of return. This is the only method that can provide the rate of return from alternative projects with different cash flows over a different time span and with different capital investment. The estimated return from this type of investment is difficult to assess and often only the data available from research, experimental farms and the more progressive commercial farms are available.

In making these assessments, like Mr Raymond of GRI, Hurley, I believe there is a need for a multi-discipline approach to the problem of conservation and utilisation of grassland. The single approach by individual disciplines is a waste of scientific resources. It is only in recent years that instead of adopting a direct substitution approach in feeding experiments it has been realized that the ruminant is capable of digesting a variety of foods, and dried grass may be a supplement to silage or hay rather than a direct replacement. The arguments for this type of approach and possible lines of future developments have been clearly stated in a paper given by Raymond[3]. The effect of cutting fertilizer treatment on different species of grassland and the diminution of feeding value at different stages of growth at different times of the year have been well documented. The pre-processed quality of grass can be modified but for most species there is an optimum point of cutting. To achieve the optimum level of digestibility and feeding value, consideration must be given to the system of conservation that can be completed in a 10–15 day period. There is undoubtedly a need for further research on optimum systems of conservation to maximise the returns from growing and feeding systems.

On most farms where grassland is an integral part, silage is the key to optimum grassland output. On suitable farms it is possible that dried grass could be the integral part of obtaining the optimum level of production. There have been changes in quality of production through improved methods of handling and harvesting both on farms where 8 to 9 million tons of hay and 3½–4 million tons of silage are produced but the optimum benefits have not been achieved because of a cheese-paring attitude towards grassland conservation. Until the last 1 or 2 years the 125,000 tons of dried grass has largely been used for supplementing the feeds for non ruminants. With the introduction of the larger high temperature driers, there is a renewed interest in dried grass, particularly in the drier eastern areas. I do not propose at a meeting with so many distinguished people present to attempt to review all the technical and scientific field, but I would like to give some thoughts on the principles underlying future developments in hay, silage and dried grass particularly as they apply to future capital investment.

2. Hay

The majority of the fodder is likely to continue to be conserved in the form of hay. Most farmers produce hay to provide bulk, and are not too concerned about digestibility and feeding value. A change in conservation method is invariably linked with changes in the system of farming, winter housing and method of feeding of cattle. Weather conditions can influence the feeding value and the quality of the final product. In view of the high risk of obtaining a low digestibility and a low feeding value, farmers go for bulk in an attempt to conserve this grass during the optimum time of production from the weather point of view. Attempts will be made during favourable weather conditions to improve the quality of the hay by killing the grass as quickly as possible to stop respiratory losses. Crimping and bruising machinery developed to date tend to be designed for less mature grassland crops which invariably increases the risk factor since hay making under these conditions has to commence during mid-May. Rates of drying in the field vary according to the severity of the treatment and the weather conditions prevailing. Wind in the form of a light breeze may often be more effective than the hot sun but little drying takes place on days of high relative humidity. A paper given by Shattock[4] indicated that freshly mown grass varies from 70–83 per cent m.c. and on good drying days the following rates could apply:—

- Unmoved swards lose moisture at ½–1 per cent per hour
- Tedded and frequently moved swards lose moisture at 1–3 per cent per hour
- Tedded with forage harvester, crimped or crushed swards, lose moisture at 2–3 per cent per hour
- Cut with forage harvester, and moved as necessary for even drying, swards lose moisture at 3–6 per cent per hour.

The risk element can be reduced by speeding up the field operations.

There is still a need to improve the present methods of baling, handling and storage. Anyone interested in looking in detail at the present forage handling systems could well refer to the paper given by Gordon Shepperson.[5] Shepperson highlights the problem areas with each system and he indicates the likely areas of development.

The problems facing the agricultural economist in advising on improved methods of hay conservation are not easy to answer, because of the variability in feeding value caused by different weather conditions and the traditionally low value that has been paid for the maintenance ration of livestock. In recent years the average price of hay has increased from £8–£10 per ton to £12–£15 per ton and such a price increase leaves some room to manoeuvre.

By reference to amortisation tables and taking different interest rates and periods of investment, the optimum level of capital investment to achieve improved feeding value can be calculated. Conventionally comparisons have been made on the cost per ton of starch equivalent or per ton of dry matter. Many people realise the shortcomings of these limited comparison figures, and tend to concentrate on the percentage losses in the field and in the store (Table I).

TABLE I

	Average % Loss of Dry Matter		
Conservation Method	In Field	In Store	Total
Field Cured Hay	25	5	30
Barn Dried Hay	10	5	15
Clamp Silage unwilted	—	30	30
Clamp Silage wilted	10	20	30
Tower Silage	10	5	15
Dried Grass	5	—	5

3. Barn Dried Hay

Although barn hay drying has been with us for many years. there has been little development except in specific areas. It is very difficult to convince farmers that the trouble of moving heavier bales from field, and placing them carefully into store justifies the additional feeding value which is theoretically sufficient to retrieve the extra cost of £2 to £3/ton. Surveys carried out by the NAAS in Lancashire and in Wales have confirmed that the theoretical performance levels have, in the majority of cases, not warranted the additional trouble and expense involved, mainly because results depend so much on the ability of the individual farmer.

4. Silage

A number of technical guides have been published by the NAAS, and one in particular refers to the mechanisation of silage making.[6] Some advisers had difficulty in using the nomographs, but this type of approach is to be commended in analysing and planning individual farm conservation systems. On most farms silage making is split into the first and second cut and in practice about two thirds of the total quantity is usually made from the first cut. For reasons of maturity and digestibility the aim should be to make the silage in 10–15 days. In this way target output per day can be estimated; for example

600 tons to be made in total
400 tons from the first cut
10 days available
Target output 40 tons per day.

This information can then be converted into acres per day depending upon the grass yield and the dry matter of the silage. Once the tonnage to be ensiled each day has been established one or two systems of mechanization within chosen limits of capital and labour resources can be selected. The load size, transport distance, turn round time, average speed and method of cutting will all affect the rate per hour. As I said at the commencement it is important to obtain the optimum physical method of production. The selection of labour and machinery combination to be used on specific farms within given ranges of output are fairly well defined. On those farms where co-operation or specialized machinery are involved this type of approach is fairly well known, for example, in the case of pea vining a minimum acreage of 350 acres must be obtained for each viner. As farm size increases and labour continues to decrease on individual farms, if co-operation is not adopted the only answer may be further capital investment in larger types of machinery in order to achieve the output necessary using a one man or two man system.

5. Tower Silos

In the survey undertaken by the NAAS on tower silos an attempt has been made to collect and analyse data from some 100 farms. This report[7] is likely to be published shortly and again confirms that the actual performance achieved is a measure of the managerial ability of the individual farmer. The variables included in this survey were:—

(1) Capital costs of equipment
(2) Feeding quality of ensiled material
(3) Intensification of production
(4) Herd size and managerial factors
(5) Motivation.

The report highlights the variation in performances achieved on different sized farms for different size of herds and different levels of management and emphasizes the danger of using average data in planning and budgeting (Table II).

TABLE II

TOWER SILO SURVEY
Summary of Averaged Data

	Mean	Range
Net cost of tower and equipment	£6159·23	£2000–14000
Net cost per cow	£68·8	£20–140
Cost per ton (potential)	£11·8	£3·0–32·9
Cost per ton (stored)	£12·95	£3·0–32·9
Cost of additional machinery per ton stored	£4·22	£0·9–7·0
Weight fed per day	52·6 lb	25–85 lb
Value dry matter	38·3%	26–56%
Value crude fibre	33·2%	25–45·9%
Digestible crude protein	8·10%	5·0–13·0%
Starch equivalent	41·9%	25·0–50·0%
Milk sales	£153·46	£100–219
Cost of concentrates	£35·52	£10·0–60·0
Vet and miscellaneous costs	£7·21	£3·0–15·0
Acres	1·32 acres	0·8–2·0 acres
Cost of fertiliser	£6·70	£2·0–14·0
Gross margin per forage acre (including forage costs)	£74·97	£30·0–130·0
Concentrates fed per gallon (winter)	3·73 lb	1·5–5·5 lb
Annual concentrates fed per gallon	2·18 lb	1·5–5·4 lb
Acres saved	0·44 acres	0·0–1·2 acres

Although 67 of the farms surveyed showed an average saving of 0·44 acres of forage used, this factor must be used with caution as the true value of the forage acres saved will depend on the alternative use of the land. Many herds would be increasing in size along with the national trend, others would be intensifying by heavy use of nitrogen and while increased stocking rates are usually associated with tower installation it is only one of the many management changes that can influence this figure. The following table provides, on an interim basis, a summary of the production data grouped by herd size and it again demonstrates the wide range in performance.

The main reasons for introducing tower silos were listed as profit convenience on two thirds of the farms and on one seventh of the farms there was a proposed increase in herd

TABLE III

Summary of Production Data Analysed by Herd size

Size Group	0–69	70–99	100–129	130+
No. of Herds	20	29	19	15
Herd Size: Average	54·45	82·21	112·42	177·93
Range	43–68	70–97	100–129	135–263
Milk per Cow Annually:				
Average (galls)	928·5	898·93	968·21	905·14
Range (galls)	520–1280	522–1241	695–1325	676–1135
Conc. per Gallon:				
Average (lb)	2·59	3·00	2·67	2·67
Range (lb)	1·56–3·80	1·60–5·44	1·80–3·70	1·68–4·00
Forage Acres per Cow:				
Average (Acres)	1·28	1·42	1·30	1·31
Range (Acres)	0·80–1·80	0·85–2·20	0·90–1·60	0·92–2·25
Fertiliser Cost per Acre:				
Average (£)	6·1	6·03	7·32	7·71
Range (£)	2·00–11·5	2·12–14·0	3·00–24·0	2·50–18·0
Gross Margin per Forage Acre:				
Average (£)	82·1	71·1	72·95	74·86
Range (£)	40·0–126·0	31·5–112·3	40·0–140·0	31·0–130·0

size coupled with incorporating a new building system. Contrary to popular belief only 2 per cent of the farmers invested in tower silos as a prestige symbol.

6. Dried Grass

Interest in dried grass originally developed in the twenties, and reached a peak in 1953 prior to the removal of rationing of feeding stuffs. Up to 1956 the product primarily met a limited market offered by compounders in the preparation of pig and poultry foods. The value and the quality of the dried grass was based on crude protein, and carotene content. The material used ranged from specially sown grasses to mowing surplus grass from airfields. Low temperature driers were primarily used in this country and it is only recently that a number of large high temperature pneumatic drum type driers, mainly of continental design, have been introduced.

The present development appears to offer new possibilities in producing dried grass for feeding to ruminants. It has been suggested that for complete utilisation of the product it is necessary to make wafers and cobs of various sizes and shapes, but the current design of packaging machines has tended to create bottle-necks and can reduce the potential output of large driers. Further it is not possible to balance or blend different materials to obtain a uniform product. Little recorded data are available on the nutritional value of feeding wafered material to ruminants as most experimental evidence in this country on the feeding of dried grass has been based upon results obtained from herbage that was previously ground and pelleted.

Based on theoretical concepts plus some observation work undertaken in this field it is possible to indicate that in arable areas, where there is scale and scope as well as mechanization ability, there are considerable economic benefits to be obtained by changing from low output, low temperature driers to the more easily controlled high temperature type. In these areas groups of arable farmers can develop dried grass as an alternative break crop. In most of the calculations it has been assumed that it is possible to produce an average 4 tons of dry matter with 65–70 per cent digestibility and that this material is capable of replacing concentrates in the ratio of 5 lb of dried grass to 4 lb of cake. To provide a satisfactory margin above the average total cost of producing dried grass (ranges from £15–£20 per ton) it is necessary with a drier of 20,000 lb operative capacity to have a minimum acreage of about 1,000 to 1,250 acres with an annual output of 4,000–5,000 tons. Based on an average of 2¼ tons of dried grass per 24 hour day this output would require a minimum working period of 25 weeks, each of 5½ days. The capital expenditure at current prices would be in the region of £70,000–£90,000 for plant and buildings and a further £15,000–£20,000 for new field and transport machinery. The daily requirement of green crop would be approximately 250 tons and provided the transport from cutting to the drying stage was organized separately it should be possible for eight men working on a two shift basis to handle this material. Implicit in calculation are the assumptions that the material is capable of being uniformly process stored and fed to ruminants at the substitution ratio of 5 lb of dried grass replacing 4 lb of cake.

7. An Example of Grass Drying Costs and Returns[8]

Assumptions

1. High temperature drier capable of an annual output of 5,000 tons
2. Acreage required 1,250 acres yielding 4 tons of dry matter per acre
3. Dried grass produced value at minimum of £24 per ton (5 lb replacing 4 lb of cake)
4. No allowance made for taxation or grant benefits that may apply.

Capital Required for Buildings Plant and Machinery	£	*Annual Costs*	£
Drier	27,000	Rent (£10 per acre)	12,500
Buildings including Bin storage	24,000	Forage costs (£16 per acre)	20,000
Waferers (Mill, cuber and associated machinery)	12,000	Fuel, oil (£3 per ton)	15,000
Field machinery	14,000	Electricity (£1·25 per ton)	6,250
Transport	6,000	Plant and Machinery Repairs (£2 per ton)	10,000
Installation costs	3,000	Labour (£3 per ton)	15,000
Miscellaneous	4,000	Miscellaneous (£0·5 per ton)	2,500
	£90,000	Sub Total	£81,250

Annual Costs Sub Total	81,250
Amortisation charge on £80,000 allowing for recovery of capital over 6 years = Annual Charge and interest charged at 10 per cent	20,700
Total Annual Costs	101,950
Total output 5,000 tons at £24* per ton =	120,000
Surplus	£18,050

Expressed as a return on total capital invested in buildings,

$$\text{plant and machinery} = \frac{18{,}050 \times 100}{90{,}000} = 20 \text{ per cent.}$$

*The break even price per ton of dried grass in this budget is £20.

TABLE IV

Adjustment of original annual margins for taxation, investment grants, subsequent investments and terminal value to obtain net cash flows.

Year	Annual margin	Depreciation allowances	Taxable income	Tax payable 42½%	Margin adjusted for tax	Investment grants	Terminal value	Net subsequent investment	Net cash flow
	A	B	C (A−B)	D	E (A—D)	F	G	H	J (E+F−H)
1	29,000	15,149	13,851	—	29,000	5,175	—	—	34,175
2	33,000	9,394	23,606	5,887	27,113	1,500	—	—	28,613
3	38,750	7,763	30,987	10,033	28,717	—	—	7,868	20,849
4	38,750	8,104	30,646	13,169	25,581	300	—	9,198	16,683
5	38,750	8,899	29,851	13,025	25,725	3,000	—	7,465	21,260
6	38,750	11,674	27,076	12,687	26,063	—	—	7,868	18,195
7	38,750	8,233	30,517	11,507	27,243	300	—	—	27,543
8	38,750	6,745	32,005	12,970	25,780	1,500	—	9,198	18,082
9	38,750	7,791	30,959	13,602	25,148	1,500	—	7,868	18,780
10	38,750	7,919	30,831	13,158	25,592	1,500	46,219	—	73,311
11	—	—	—	13,103	(−)13,103	—	—	—	(−)13,103

Provided the performances implicit in the above budget can be achieved there is scope for expanding grass drying to meet potential increases in demand in the 'traditional' market at home and abroad, and particularly as world prices of cereals and protein continue to rise as a substitute in rations for ruminants.

With these assumptions it is possible to list the capital required for buildings, plant and machinery and to obtain the annual costs associated with this enterprise. In a simple form this can be shown as follows:—

When making an assessment on an individual basis it is necessary to specify the assumptions underlying the calculations. Kerr[9] fully discusses this approach and suggests that in any capital appraisal it is necessary—

(1) to specify the life of the project;
(2) the terminal value of the capital investment;
(3) amount of initial and subsequent investment of net capital;
(4) to calculate the annual cash flow of income over expenditure before charging depreciation and interest;
(5) to adjust the annual cash flow for tax allowances, tax payments, investment grants and terminal value.

In this way the net cash flow (Table IV) is obtained and the discounted yield can be calculated (Table V). In the example Kerr assumed a life of 10 years and used the data tabulated above.

TABLE V

Discounted yield calculation

Year	Net cash flow £	Discount factor at 20%	Present value £	Discount factor at 30%	Present value £
1	34,175	0·833	28,467·8	0·769	26,280·6
2	28,613	0·694	19,857·4	0·591	16,910·3
3	20,849	0·578	12,050·7	0·455	9,486. 3
4	16,683	0·482	8,041·2	0·350	5,839·1
5	21,260	0·401	8,525·3	0·269	5,718·9
6	18,195	0·334	6,077·1	0·207	3,766·4
7	27,543	0·279	7,684·5	0·159	4,379·3
8	18,082	0·232	4,195·0	0·122	2,206·0
9	18,780	0·193	3,624·5	0·094	1,765·3
10	73,311	0·161	11,803·1	0·072	5,278·4
11	(−)13,103	0·134	(−)1,755·8	0·055	(−) 720·7
Total	264,388		108,570·8		80,909·9

Calculation to find by interpolation the rate of discount at which the sum of the net present value is equal to the original investment.

Present value at 20%	=	108,570·8
− Present value at 30%	=	80,909·9
		27,660·9
Present value at 20%	=	108,570·8
− Capital	=	106,000·0
		£2,570·8

$$\frac{2,570\cdot8}{27,660\cdot9}\times 10\% = 0\cdot9\%$$

Discounted yield $= 20\% + 0\cdot9\% = 20\cdot9\%$

Note:
Use of 20% and 30% discount factors. When annual net cash flows vary the discounted yield can only be found by trial and error and it is advisable to take fairly wide limits to avoid having to recalculate. In this case, it is anticipated that the return will fall somewhere between 20% and 30%. The exact rate is discovered by interpolation.

A satisfactory yield is obtained, i.e. 20·9 per cent. The project is feasible since there is a positive net cash flow and sufficient margin left to repay capital if this was borrowed, as shown in the last column of Table IV.

During the past few years the NAAS have been looking fairly carefully at investments of this type and actual levels of performance achieved come very near to the budgeted information, particularly after adjustments have been made for the increase in the capital costs of machinery that took place from the planning to the implementation stage. A similar evaluation has been undertaken of the Taarup Uni-dry and careful records have been maintained on the percentage dry matter, fibre, D-value, SE and digestible crude protein of the dried grass. As with most types of machinery during the first year in most cases there have been a large number of mechanical problems and breakdowns. This particular type of drier is designed for mixed farms and uses farm labour to operate it. About 750 tons of dried grass was produced from 250 acres in single and multiple cuts. Approximately 4,500 tons of fresh grass was fed into the drier to achieve this output. The cost per ton of dried grass produced was about £20–£21 per ton, after allowing for depreciation, repairs and drier and field costs.

Looking to the future with a possibility of a continued rise in cereal prices it is possible that the hot gospelers may be forecasting a very lucrative return from dried grass. Increasing land price, machinery and labour costs may take up this additional margin. At times when capital is short plus the returns from livestock at a marginal level, it would be advisable to undertake a very critical appraisal of any capital investment using the cash flow approach. It would be advisable to vary the returns as well as some of the costs in order to arrive at the different break even points or the point at which investment would be worthwhile. The selection of single figures can in a precise technique such as DCF give equally misleading results as the simple approach using single figures by any other method. Provided that the distance of moving dried grass is not much more than 30–50 miles there are certainly possibilities of bringing in dried grass in those areas where a grass break is desirable from a rotational point of view.

7. Conclusions

To sum up, there is a need to identify the managerial skill of the individual or group of individuals and to design the system of conservation to match the level of management within the constraints of land, labour and capital. Greater precision must be used to ensure that the optimum technical or physical performance is achieved before economic yard sticks are applied. Having achieved the optimum physical method an economic analysis should then be undertaken to assess the benefits of one particular method against another. Initially average costs are the only means of presenting a static budget, but it would be quite wrong to take single figures. Calculations should be made using a range of costs and returns. There is a need to list the capital investment and to include taxation allowances and grants that may be available to individual farmers or groups of farmers. The net cost of the capital investment should be obtained. The capital appraisal should be undertaken to ascertain the worthwhileness and feasibility of a particular investment utilizing the cash flow method of calculation.

General guide lines have been given in this paper and I have tended to outline principles rather than detail. We can only make further progress in this field of grass conservation if there is a multi-discipline approach by those involved in research, development and advisory work. In designing machines to fit mechanization systems every effort should be made to utilise fully the information available from the plant breeder, nutrition chemist, etc. In this way there will be a reduction in the biases and prejudices of individual research and advisory workers and a more objective approach made to the many facets of this nebulous field of grassland conservation.

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Engineering Aspects of Green Crop Conservation

DISCUSSION
(Edited Report)

Chairman : J. H. W. WILDER, OBE, BA, FI Agr E*

Conducted during the Annual Conference of the Institution in London on 6 May 1971

Mr D. F. Ellam (University of Reading) described a system of handling, storing, drying and unloading chopped hay, on which he had been working, with support from the Electricity Council. The system comprised several distinct stages, each fully mechanized. The grass was cut initially by a drum mower and, after wilting to about 45–50 per cent moisture content, was picked up, chopped and delivered into conventional tipping trailers by a full-chop forage harvester. The chop length averaged about 4 in.

At the storage building, the trailers were tipped into a dump box, which delivered the material to an elevator. The elevator delivered it in turn to a horizontal conveyor suspended in the apex of the roof of the building, and the crop was discharged from the conveyor into one of two storage bays. Alternative means of distributing the hay in the store had been used. At one stage, a distributor with contra-rotating tines was fixed to the discharge point of the horizontal conveyor, which was capable of moving progressively across the length of the storage bay. Subsequently, the unloading equipment had been used as a distributor, with a suitable deflector to spread out the incoming hay.

Drying in store was by means of the 'Dutch' system, blowing unheated air from an underground plenum through a vertical duct formed in the hay as it was loaded into the store. A large centrifugal fan was used for this purpose.

The unloading equipment also made use of the vertical duct and underground passage. It consisted of a single horizontal auger supported on a central pillar, which was driven round and lowered continuously to scrape off a layer of hay and move it to the centre of the storage bay, where it fell down the vertical duct. From the base of the duct the hay was carried away by conveyors, either to a forage-box trailer or directly to stock in the adjacent building.

Difficulties had been encountered at several points in avoiding blockages, but the system as a whole appeared to offer scope for commercial development at a cost which should be competitive with imported hay tower systems.

Dr J. G. M. WOOD (Consultant) congratulated Messrs Shattock and Catt on a very well-balanced paper. The figures for rate of filling tower silos based on 10 ft. of height/day could now be increased, in the light of further work which took account of crop moisture content and the rate of heat production in store. In addition, a new British Standard on tower silos was now available, the recommendations of which could be followed with complete confidence by farmers. It was true that in the past silos had collapsed in some cases when filled with wet silage. The new recommendations would not entirely avoid damage due to filling with material which was unduly wet, but gave adequate safeguards against structural collapse.

The barn hay drying system that Dr Wood had developed at Newcastle University was specifically aimed at the growing group of farms in the range of 150–300 ac. The equipment was not very complicated and was much simpler than that found in grain drying systems, and it was able to dry hay in the barn from a moisture content of 60 per cent, so that a very high quality material could be produced.

Mr H. A. THOMAS said that while Dr Wood's hay system was of great interest, it was always dangerous to try to apply research ideas in farming practice without proper engineering development.

Mr D. J. GREIG (University of Newcastle) pointed out that the film shown had depicted Dr Wood's system in the course of development, during which a sound basis for engineering refinement had been provided. Farmers were increasingly becoming well educated to deal with engineering developments.

Mr W. L. HEARLE (Western Electricity Board), referring to Mr Greig's paper, said that he was suprised the protein equivalent of 'top quality' hay was quoted as only 5 per cent. He would have expected it to approximate to the 13 per cent quoted for silage. The advantages of barn-dried hay as a high quality product were widely appreciated, but it was true that it had not been widely adopted, largely because of the handling involved. Any development which could reduce the amount of manual handling was most desirable, and he congratulated Dr Wood and others at Newcastle for the contribution their system made. It was a complex piece of equipment, but certainly no more complex than the pick-up baler and other equipment to which it provided an alternative. While reference had been made to respiration losses in the barn drying process, he did not imagine these were any greater than similar losses in the field with conventional systems.

Mr Hearle went on to suggest that the barn hay drier was not necessarily inflexible in dealing with a varying rate of grass growth, in which it had been said to be limited in the same way as a grass drier. If hay had to be stored in a building in any case, the only additional cost in providing greater capacity was that of fan power. He asked if there might not be advantages in using a flail mower as the primary cutting mechanism, and if close-welded mesh sides to the building could not be used rather than airtight panels and if a different type of air distribution chamber might not have enabled a lower building cost to be obtained. Further, he asked if the moisture evaporative capacity of 25–30 cwt/day had been calculated or measured, and by what factor the cost of installation would rise if the size of the unit was multiplied by four.

Mr D. J. GREIG said that the figure of 25–30 cwt/day was obtained from Electricity Council data for the output of fans based on a temperature rise of 5°F. This had been checked by a measurement of drying rate and it was found that the theoretical rate was in fact being achieved. As regards

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construction of the drying bays, airtight sides were necessary to obtain a parallel airflow pattern through the stored hay. The floor was of welded mesh supported on concrete blocks.

Dr J. G. M. WOOD said that the installation shown on the film was a two-bay unit. It would be a simple matter to construct a unit up to four or six times as large. It would be necessary to carry out a feasibility study on the economic aspects first.

Mr H. PATERSON (Electricity Council) said that two hay towers had been in use in Britain during the last two seasons. One was a full-height tower, and the other of the Dutch type with a rising roof. Both operated on the radial ventilation principle and both, with good management, could produce well-dried, high quality material. From the engineering point of view both were fully able to handle material chopped to 4–8 in. nominal length, loading, distributing and loading out for feeding. Their capacity was 150 t. of dried hay, in both cases.

Mr Shepperson had said that the future of the hay tower depended on economic factors, and this was perfectly true. But Mr Paterson wished to emphasize that, operated as a 1-man system, as was one of the two installations he had referred to, this must be compared with a 1-man system for handling and drying baled hay. Such a system would involve handling 9000 hay bales, and at present manual handling would be required in the final positioning when loading into storage, and again when loading out. This would require 18000 manual bale movements, which was beyond the capacity of 1 man. The apparently high capital cost of the 1-man hay tower must be considered in the light of this comparison.

Mr W. S. SHATTOCK said that the timing of operations was a factor to be borne in mind. Many farmers made a large quantity of hay in a short period of favourable weather and the tower system was well suited to such conditions. It was probably not as suitable in circumstances where small quantities of hay were made at frequent intervals.

Mr D. J. B. CALVERLEY (ADAS) said that it was important to consider how conserved feeds were used, and where 1-man systems of conservation were in fact in operation. Few 1-man systems were now in use because 1-man systems did not exist, generally speaking. Trends in farming were towards larger and larger herds, with a smaller number of men on the farm, and the question of who would be actually doing the work of conservation was a point to which engineers and agronomists had paid insufficient attention. The Newcastle chopped hay system, the hay flake system and the hay tower were all systems of continuous conservation which had to be associated with proper grassland management, so that one man working a small number of hours a day throughout a long growing season could conserve fodder—or, if not one man, a small gang. The only alternative was a large gang working for a short period making silage. But increasingly in the future farms would not be able to provide sufficient men to enable large gangs of men to be available. One-man conservation systems would be urgently needed and must be developed, initially irrespective of economic considerations.

Mr C. MONCK (Farmer, Berkshire) pointed out that the grazing animal constituted a no-man harvesting system, and that a consideration of this feature of grazing animals, as continuous mowing machines, could be helpful in a theoretical analysis of conservation systems. Grazing was a more efficient method of utilizing nutritive material than was conservation. Conserved material fed in winter had to be supplemented with concentrate food. The quality of conserved food was very important, especially when the operations associated with conservation had to continue over a long period, as Mr Calverley had suggested they should.

Silage making and hay making were both limited, by considerations of manpower and weather conditions respectively. In development work on the hay flake system with which he was associated, Mr Monck had found that weather conditions did not permit rotational harvesting of grass regularly on a 35-day cycle, comparable with rotational grazing by cattle unless total drying facilities were incorporated in the system.

These considerations led to the selection of a non-continuous drying system, because on most farms the cost of a continuous, high-temperature drier would be prohibitive. A batch system of drying, utilising medium rather than high air temperatures, was therefore to be advocated on a normal farm scale, in spite of the advantages of the high-temperature drier in terms of fuel efficiency.

Mr GREIG pointed out that the high-temperature drier could be started and stopped with little loss of efficiency, but agreed that while it was operating it had to have a constant supply of wet grass, with constant removal to storage of the dried product.

Mr H. A. THOMAS said that one could not be dogmatic about 1-man or 2-man systems, batch or flow systems, or grazing animals. Careful attention to the management of grassland production, based on Mr F. Raymond's work, could lead to almost continuous production of grass. This pattern of production must be taken as the basis for engineering development of conservation systems, and it would be necessary to select different systems in different circumstances to obtain the best results.

Mr P. G. FINN-KELCEY (Consultant) said that he was disappointed Mr Shepperson had not suggested some more forward looking ideas. For example, most people felt that baling would continue to be used as a packaging technique for a long time to come. But one must design handling systems for bales without incorporating in them any need for manual handling, right to the last point in the handling sequence. The designer was free to vary the size of the bale, if he chose, and Mr Finn-Kelcey was aware of the experimental work on very large bales which had been done at the National Institute of Agricultural Engineering, but he felt there was much to be learned from American experience with automatic bale collecting and handling machines.

Similarly, American work on wafering was at an interesting stage of development, and Mr Finn-Kelcey thought that the hay wafer, produced at perhaps 40 per cent moisture content in the field and then dried in storage, was the method of hay packaging which would be universal in ten years time.

Turning to Mr Catt's paper, he asked what was meant by a 'high rate' of filling tower silos. He felt that a rate of two tons a minute was desirable and that engineers should try to devise a method of achieving this which did not incorporate a fan mechanism.

Mr G. SHEPPERSON said that he had spent 4 days in California in 1968 and had seen the American equipment Mr Finn-Kelcey had mentioned. He had also immediately become conscious of its limitations for use in Britain. Some of the bale-handling machines had been brought over to this country, but they had not caught the imagination of British farmers, who probably regarded them as too big and too expensive for their hay enterprizes. He felt that some of the American approaches to hay wafering were also less likely to prove satisfactory in temperate climates than the roll-wafering method which was now under development in Germany and also in the U.S.A.

Mr. Shepperson did not think very large bales offered much hope for the future, and work at the NIAE on them had been discontinued. However, the large-bale system was a 1-man system and it might offer considerable advantages in this context.

Mr W. R. CATT replied that in his view 16 ton/h. was a desirable rate and 20 ton/h a high rate, representing 4 ac./h. In fact, there were several types of blower available in this country that were capable of achieving these rates, at least on a spot basis. The factor that prevented continuous rates of 16–20 ton/h. from being achieved was probably connected with feeding the crop to the blower, whether from dump boxes or from forage boxes. There was an engineering problem at that point which warranted urgent attention.

Dr J. G. M. WOOD (Consultant) said that one of the student design projects he had been associated with at Newcastle was the development of a mechanised elevator capable of a delivery rate of 20 ton/h., requiring 15 hp to drive it, compared with the 60 hp typically required to drive a blower. It was available to any manufacturer who wished to purchase it. Replying to a question from **Mr C. A. HARRIS** (Agricultural Engineers' Association), Dr. Wood went on to say that the optimum height of tower silos depended on the moisture content of the crop. With material wilted to 50 per cent moisture content, it could be stored up to 65 ft. high—the dryer, the higher.

THE CHAIRMAN (Mr J. H. W. Wilder) remarked that silo height was one of the planning considerations which could affect the success of a silo installation. In one case he knew about, the planning authorities had not permitted the farmer to instal two 60 ft. silos, so that he put in four 40 ft. silos instead, which made the whole installation unsatisfactory.

Mr F. RAYMOND (Deputy Director, Grassland Research Institute) said that knowledge of the nutritive values of different types of grass had been available for some years, but had had no effect on the production of grass. The cost of alternative foods had been so low that it had not been worth while to make better-quality hay or silage. But economic and political factors were now combining to make these alternative feeds expensive, which would encourage better conservation of grass. It was important to remember the date of any information on costs, and Mr Thomas's figure of £24/ton for dried grass, which no doubt applied in 1968, was now completely out of date. £24/ton now represented the production cost rather than the purchase price.

It was increasingly important to adopt a systems approach, with engineer, nutritionist and economist working together, because the system was sensitive to apparently small changes in costs. The latest information on the feeding value of dried grass suggested that the replacement ratio for dairy cake was nearer 4·5:1 than 5·0:1. The effect of such a change on the costs Mr Thomas had given was quite phenomenal.

Mr H. A. THOMAS confirmed that the dried grass costs he had quoted referred to 1968. In 1970 the production cost would have been £22/ton and the selling price £26 or £27/ton. The relative advantage still held, and when taxation allowances or grants were included the position was still more favourable.

Mr R. V. FALKINGHAM (ADAS, Somerset) said that several conventional barn hay driers were working in his county. The farmers concerned would not make silage on dried grass, and the barn drying method avoided mouldy hay and the respiratory diseases problems associated with it.

Mr. SHATTOCK said that in the south-west 80 per cent of the fodder was conserved as hay, and one-fifth of these farmers could possibly benefit from barn drying. In one case he knew, an outlay of £1400 was recovered in a single year, and better quality could be obtained by taking a second hay harvest and drying it in the barn.

Mr P. A. M. MURRAY (Farmer) said that one of the current problems was in matching the working rate of successive stages in the haymaking process. Balers operated at 5 ac./h., swath-turning equipment at 7-10 ac./h., but mowers were limited to 3 ac./h., especially if associated with a crop conditioner. The speed limitation of tractors to about 7 mile/h. was a problem with roller-crushers which worked best at a speed faster than 7 mile/h. He asked if the special flails Mr Shepperson had referred to had any beneficial effect in terms of speed of operation.

Mr G. SHEPPERSON said that early work had shown that a flail mower used after a reciprocating mower gave a laceration effect similar to crimping or crushing, with an equivalent drying rate. He requested Mr Brown, of the NIAE to describe the current work on flail mowers.

Mr BROWN (NIAE) said that his work was concentrated on the finger bar mower, with the intention of treating the stemmy part of the crop more severely than the leaf. The forward-acting flails were mounted directly over the cutter bar so that they hit the butt ends of the cut crop. They had not lost sight of the possible use of a knocker wedge as an additional mechanism on the drum mower.

THE CHAIRMAN said that the effect on the crop of flail mowers depended not only on the type of flail mower, but also on how it was used. One of the problems was in getting grass to flow from one stage to the next.

Mr P. H. BAILEY (University of Newcastle) said that the cost of drying grass with the experimental drier in a rather wet part of Northumberland was £15/ton for variable costs and £10/ton for fixed costs. Work he had been concerned with 20 years earlier at the NIAE, which at least had not been disproved by the recent work at the NIAE of Messrs Brown and Comely, showed that a short period of wilting—perhaps for only two hours—could have considerable economic benefits. Losing water in this way had very little effect on the nutritive quality of the grass, but it greatly increased the output of the drier and reduced both the fixed and variable costs/ton of dried grass.

THE CHAIRMAN said that wilting undoubtedly had these advantages, but that the whole point of grass drying was to be independent of weather. If one introduced a wilting stage, immediately the advantage of weather-independence was lost. In his view, grass drying processes must be designed to be economically sound without wilting. □

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admissions and transfers

At a meeting of the Council of the Institution on 29 April 1971 the following candidates were admitted to the Institution or transferred from one grade to another, as stated below.

ADMISSIONS

Member

Horspool, G. D.	*Malawi*
Lees, D. J.	*Staffs*
Ramalingam, S.	*Ceylon*
Redman, S.	*Trinidad*

General Associate

Baster, S.	*Essex*
Bruce, N. J. A.	*Warwicks*
Davis, J. N.	*Lincs*
Dewar, P. A.	*Zambia*
MacNab, D.	*Essex*
Morris, A. B.	*Norfolk*
Rea, S. W.	*Warwicks*
Smith, A. M. M.	*Hereford*
Ward, P.	*Warwicks*
Welton, J. R.	*Perth*

Technician Associate

Barker, D.	*Warwicks*
Brown, P.	*Warwicks*
Clarke, R.	*Staffs*
Griffiths, R. A.	*Worcs*
Morgan, C. E. L.	*Staffs*
Sargeant, W. J.	*Cornwall*
Scown, J. J.	*Lincs*
Stanton, R. H.	*Warwicks*
Summerscales, J.	*Carms*
Travis, J.	*Yorks*
Turner, T. E.	*Warwicks*

Graduate

Gyarteng, O. K.	*Beds*
Langley, A.	*Edinburgh*
Pullen, D. E. H.	*Northumbs*
Roche, M. J.	*Yorks*

Student

Garlick, B.	*Warwicks*
Giles, D. F.	*Staffs*
Gundry, R. G.	*Warwicks*
Hobbs, R. M.	*Herts*
Lawson, I.	*Warwicks*
Orchard, R. W.	*Worcs*
Perry, P. J. E.	*Warwicks*
Tan, A. S.	*Malaysia*
Temple, S. J.	*Norfolk*
Tutt, P. G.	*Kent*
Walker, W. J. K.	*Northants*
Wells, P. J.	*Lincs*
Winlo, B. P.	*Yorks*

TRANSFERS

Member

Bowyer, M. J.	*Warwicks*
Dennis, C. W.	*Cambs*
Garland, P. J.	*Australia*
Lucas, G. S.	*Cameroon*
Martin, M. S.	*Norfolk*
Rooprai, A. S.	*London*
Webb, P. A.	*Wilts*

Technician Associate

Aldis, C. A.	*London*
Burns, M. R. A.	*Warwicks*
Owen, J. N.	*Salop*

Graduate

Chaudhary, F. M.	*W Pakistan*
Davis, R. A.	*Herefords*

Paper by J. R. O'CALLAGHAN and D. J. GREIG

from page 80

Field wilting is uncertain due to its dependence on the weather.

High temperature grass drying is the only conservation method by which grass can be converted with certainty into a cash crop of predictable quality. The capacity and capital cost of most grass dryers requires that they should be operated on a commercial scale. Given good management to regulate cutting, which gives a high protein content and as great an annual throughput as possible, good returns can be obtained on capital.

On-farm high temperature grass drying requires low cost plant because the demand for dried grass within most farms is less than 100 tons per annum. Simulation studies have shown that the large volume of a drum dryer is poorly utilised. Studies on drying of thin layers of grass have provided accessible data for design of driers in all practical temperature ranges.

An economical method of improving the reliability of on-farm drying is the storage type of barn hay dryer in which it has been shown that it is possible to distribute the hay in a bed of uniform density, a prerequisite for uniform drying.

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