Journal and Proceedings of the Institution of Agricultural Engineers

MARCH
1965

Vol. 21 No. 1

JOURNAL AND PROCEEDINGS OF THE INSTITUTION OF AGRICULTURAL ENGINEERS

IN THIS ISSUE

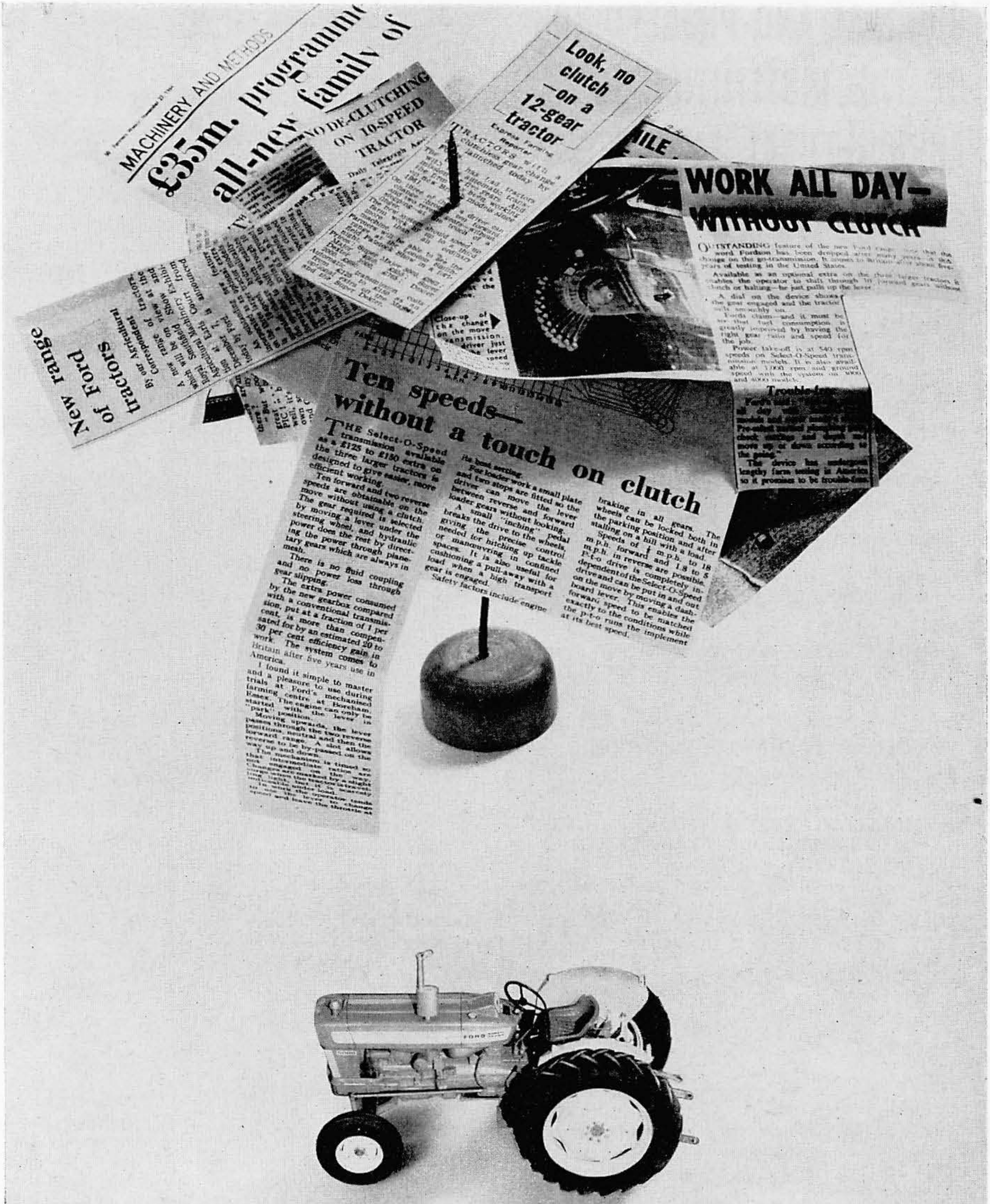
Page

Published Quarterly by the Institution of Agricultural Engineers, 6 Queen Square London W.C.1

Telephone: Terminus 0140

Price: Ten Shillings and Sixpence

VOLUME 21 **NUMBER 1** **MARCH 1965**



1965–The year of the all-new Fords

THE NEW NATIONAL DIPLOMA IN AGRICULTURAL ENGINEERING

by

D. I. McLAREN

BSC(AGR), NDA, MI AGR E, Chairman of the Examination Board in Agricultural Engineering

Mr McLaren joined the Institution as a Member in 1950. He was elected to the Council in 1952 for three years and served on various Standing Committees. It was in 1962 that Mr McLaren, with his special interest in education and training was appointed Chairman of the Examination Board in Agricultural Engineering, the position he still holds today. By virtue of that appointment he is ex officio a member of Council and the Membership Committee. Mr McLaren has held various staff appointments with the National Institute of Agricultural Engineering, Silsoe, since 1946, his present position being Head of the Mechanization Division.

The Examination Board

Ever since its foundation in 1938 the Institution of Agricultural Engineers has regarded education as a vital part of its activities. This concern for the future professional development of Agricultural Engineering led to the establishment in 1950 of the Examination Board in Agricultural Engineering.

The Board's membership is drawn partly from the Council of the Institution of Agricultural Engineers and partly from representatives of teaching centres, industry, relevant Ministries and other official bodies. A secretariate is provided by the Institution, whose Assistant Secretary is also the Board Secretary. The Board is partly self-financing through examination fees and the sale of publications, but the main cost of its work is borne by the Institution. The Board is thus autonomous to a considerable extent, but without the support of the Institution it could not continue.

History of The Board's Examinations

The Board is responsible for two main examinations—the National Diploma in Agricultural Engineering (ND AGR E) and the Institution Examination (formerly called the Graduate Membership Examination). An Intermediate Examination, which formed a preliminary qualification leading to ND AGR E courses, was also provided until recently.

In 1951, when the ND AGR E examination was first held, no other national qualification in agricultural engineering was available. The Examination Board thus took the initiative in making provision for the award of a qualification which would be of value to aspiring professional agricultural engineers and to potential employers. As a secondary consideration, the ND AGR E was accepted as a qualification leading to membership of the Institution.

Later, because the ND AGR E is normally taken immediately following a one-year full-time course of instruction, which is not always available to or suitable for some candidates for professional membership of the Institution, the Institution Examination was introduced to provide an avenue of entry for such candidates. In making this provision the special needs of mature candidates with considerable practical experience were considered.

The Revised ND AGR E

Standards of technical performance tend to increase continuously in every field, and this is true in agricultural engineering as in other technologies. While the level of performance demanded in the ND AGR E has increased quite markedly in the fourteen years since its inception, recent decisions by the Board are intended to raise the standard yet higher in 1966, while at the same time allowing a measure of specialization in one or more broad areas of agricultural engineering. As before, the ND AGR E courses are designed to follow first qualifications in Engineering or Agriculture. New outline syllabuses for both approaches to the ND AGR E have been drawn up by the Board to provide guidance for the teaching centres it approves (at present the Essex Institute of Agriculture at Writtle and the West of Scotland Agricultural College in Glasgow). The centres are then free to submit detailed syallabuses for the Board's approval. In this way each centre can develop courses in Agricultural Engineering which make the best use of the teaching and other facilities available, within the scope provided by the Board's outline syallabuses.

With the new and still further improved syallabuses there goes a new examination structure, again allowing greater flexibility than hitherto. The examiners appointed by each recognized teaching centre will submit their examination papers to Assessors appointed by the Board for approval. The Assessors will be responsible for assessing the marks awarded to each candidate by the centre's examiners (who will be drawn both from outside the centre, as well as from teaching staff at the centre) and for assessing the performance of the candidates in relation to the standard required for award of the ND AGR E. The National Diploma will be awarded to candidates attaining a satisfactorily high level of performance.

The Institution Examination

For some time it has been apparent that the Institution Examination was not fulfilling its original purpose of providing an avenue of entry to professional membership of the Institution for mature candidates who for some good reason could not take the ND AGR E. Instead, it had become a semi-professional qualification in its own right, at a lower level than the ND AGR E. Since enhanced facilities for the ND AGR E courses and accommodation for larger numbers of students are becoming available at the Essex Institute and at Glasgow, and since it is now possible for the best of the candidates holding the City and Guilds Agricultural Engineering Technician's Work Certificate to enter for the ND AGR E, there is no longer a case for allowing young candidates to enter the professional ranks of the Institution via the Institution Examination.

The Institution Examination, from 1966 onwards, will therefore only be available to mature candidates (of 30 years of age and above), for whom it has now been specially designed.

The details of the new arrangement are set out on page 11 of this issue of the *Journal*. While membership of the Institution is not the concern of the Board, it should be pointed out that, from 1966 onwards, passing the ND AGR E (or, for candidates of 30 or over, the Institution Examination) will admit to Graduate Membership. After a suitable interval of time, Graduate Members will take a Part III Examination, to test their professional development, and on passing Part III will be eligible for Associate Membership.

The ND AGR E In Perspective

The scene has changed greatly since the ND AGR E began in 1951. In particular, the National College of Agricultural Engineering has been established to form the spearhead of agricultural engineering education at degree level, while at technical level the City and Guilds Agricultural Engineering Technicians course (No 261) and the Ordinary National Diploma course in Engineering with an Agricultural Engineering bias are valuable provisions. Post-graduate courses at the Universities of Newcastle and, more recently, Reading, provide for the top-level technologists and it is possible that undergraduate university courses may also be established eventually.

The Examination Board, in bringing out its revised ND AGR E syallabuses, is confident that Diploma holders will continue to find ready employment in very many sections of the agricultural engineering and mechanized farming industries, at home and overseas. The syllabuses have been drawn up in close consultation with the Agricultural Engineers Association, the Agricultural Machinery and Tractor Dealers' Association, the Department of Education and Science and all the teaching centres concerned. It is hoped that an increasing number of employers will be prepared to sponsor suitable candidates wishing to take the revised ND AGR E courses.

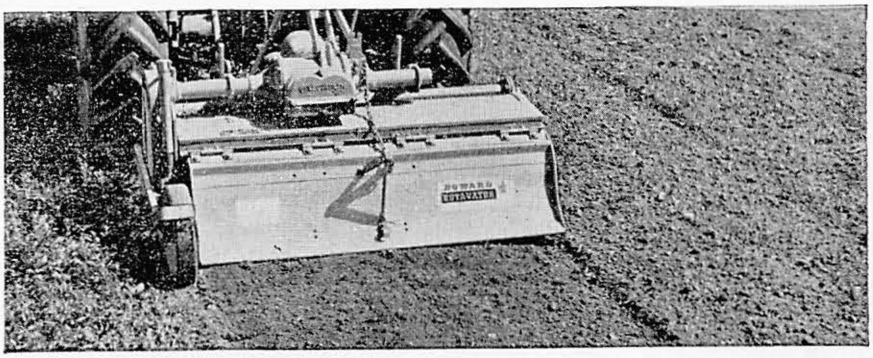
The Board envisages a long-continuing future for the ND AGE E as a worthy qualification which meets a particular need in the now complex pattern of agricultural engineering educational provision. The Institution of Agricultural Engineers endorses the Board's view by taking the ND AGR E as the yardstick of technical competence on which Graduate Membership and subsequent professional membership of the Institution will in future be based.

HAYTIME WITH HOWARD

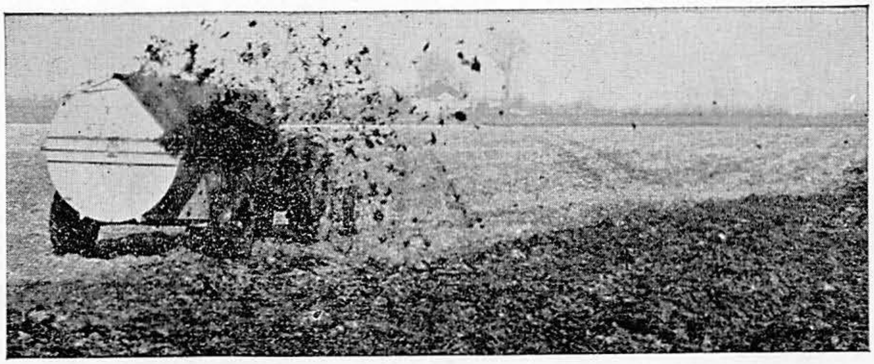
The new HOWARD HAYTIMER cuts, bruises and windrows in one operation. With its 6 ft. cut the Haytimer provides a fast nonstop process of hay or silage making. Better quality hay with a shorter drying period, reducing baling delays, cuts making time in half and reduces the weather risk. Easily adjustable windrows and cutting height makes light work of the heaviest crop likely to be met in the British Isles.

FARM ECONOMY—THE HOWARD WAY

In every branch of farming
agricultural principles
remain constant.
The economical working
of every operation
is essential to
profitable farming.
Howard equipment combined
with good husbandry
bring to the farmer
all the benefits to be
gained from good seed-beds,
better use of land,
even spreading of solid
or liquid manure,
and efficient haymaking.
Using Howard equipment
is a step in
the right direction.



The 'E' SERIES III Rotavator provides controlled tilth quality in seed-bed preparation, stubble cleaning or pasture renovation. With its variable rotor speeds and accurate depth control the Rotavator can do so many jobs on a farm.



The HOWARD ROTASPREADER handles all manure; solid, liquid or slurry. Power drive gives a sustained performance with an even 10 ft. wide spread. 3½ and 7 cubic yard models are available.

FROM THE WORLD'S LARGEST MANUFACTURER OF ROTARY TILLAGE EQUIPMENT

By Appointment to Her Majesty the Queen Manufacturers of Agricultural Equipment Howard Rotavator Co. Ltd.

HOWARD ROTAVATOR

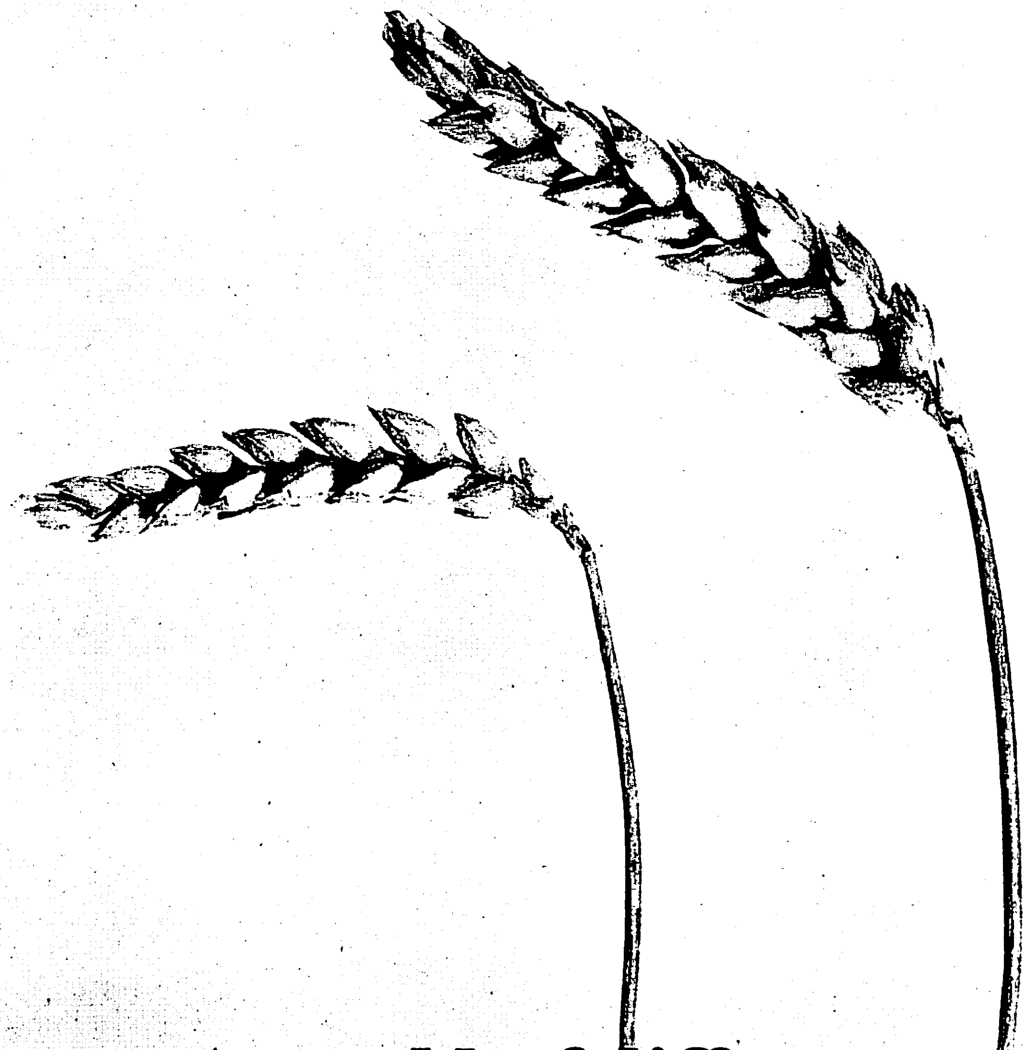
REGD. TRADE MARKS

HOWARD ROTAVATOR CO. LTD., WEST HORNDON, ESSEX

TEL: HORNDON GREEN 361 — TELEX: 1961 — CABLES: ROTAVATOR BRENTWOOD

AUSTRALIA · E. AFRICA · FRANCE · GERMANY · ITALY · NEW ZEALAND · S. AFRICA · U.S.A.

If you cannot spell it backwards—it is not a ROTAVATOR



A world of difference

Most diesel tractors and combines are Perkins powered . . . and most farmers realise that the extra savings they get every day from Perkins add up to really significant amounts in year-round usage. What appear to be only small differences in actual fact make all the difference in the world. No wonder so many far-sighted farmers standardise with Perkins, not only in specialised farm machinery, but in trucks, vans and other equipment around the farm. For lower costs and substantially larger economies it pays to make sure it's a Perkins. Parts and service are readily available and a hand-picked distributor who specialises in Perkins is never more than a phone call away.

make sure it's a PERKINS

Perkins Engines Limited, Peterborough, England.

INSTITUTION NOTES

Redesigned Journal

As announced in the previous issue of the *Journal*, this first issue of 1965 is noteworthy not only for its restyled appearance but also by virtue of some new features. Chief among these is the Guest Editorial. The purpose of this is to enable thoughtful consideration and comment to be offered by leading personalities on topics of current national importance with special reference to agricultural engineering. Alternatively, a Guest Editorial may be the means of voicing a major policy decision of the Institution, or it may comment upon the main subject or theme covered by the *Journal* in which it appears. It is hoped during 1965 to provide increased coverage in the *Journal* to reporting Branch activities and to offer facilities for classified advertising.

Publication dates until further notice will be March, June, September and December.

Education and Training

In this issue, a feature article describes the intensive developments that have occurred in reorganizing the structure of the Institution's examinations, with special reference to the National Diploma in Agricultural Engineering (ND Agr E). Such is the crucial importance of these developments within the context of technical training in the industry as a whole that Mr D. I. McLaren, Chairman of the Examination Board in Agricultural Engineering was invited to contribute the Institution's first Guest Editorial which appears in this issue.

The Year Book

The future of the *Year Book* has been under review for some time and it can now be announced that publication is to continue, as a result of widespread demand from members. It is to be considerably reorganized and its appearance in 1965 and subsequent years will be somewhat similar to the *Journal*, both in styling and page size. The alphabetical list of members will be retained and will be presented in a form offering greater clarity than has been possible in the past. The book will be published towards the end of August.

Extraordinary and Annual General Meetings

The Annual General Meeting of the Institution will be held during the morning session of the Annual Conference which will take place in the Main Hall of the Institution of Mechanical Engineers, 1 Birdcage Walk, London SW1 on 22 April 1965.

Immediately preceding the AGM, there is to be an Extraordinary General Meeting at which members will be invited to approve a series of amendments to the Articles of Association. The proposed amendments, details of which will be circulated with the Notice and Agenda of the meeting in due course, will have regard to the revised examination structure in relation to Graduate and Corporate membership, to changes in the Council structure (such as providing for a Graduate member to be elected thereto) and a variety of relatively minor alterations aimed at keeping the Institution on a modern and progressive footing.

Forthcoming Conferences and Exhibitions

Chemicals and the Land

The Yorkshire (WR) Institute of Agriculture announces a Symposium on the above theme at Askham Bryan, Yorks, during the period 12-14 April 1965. It is open to farmers, gardeners, naturalists, scientists and all others interested in the use of chemicals on the land in relation to the welfare of man. Enquiries should be addressed to the Secretary General, Cliftonfield, Shipton Road, York.

European Agricultural and Industrial Fair (ELMIA 65)

With an extensive international participation, this well-known trade fair is this year taking place during the period 3-13 June 1965 at Jönköping, Sweden. In addition to national exhibition sections, the EEC Commission in Brussels is to arrange a comprehensive conference on various aspects of the common agricultural policy within EEC. Further details of the occasion can be obtained from the General Secretary, ELMIA 65, Jönköping, Sweden.

Royal Show

The Royal Agricultural Society of England announces that the 1965 Royal Show will take place at Stoneleigh Abbey, Kenilworth, Warwicks from 6th-9th July inclusive. Further information may be obtained from the Secretary and Technical Director of the Society at 35 Belgrave Square, London SW1.

Reprint Service

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

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

Reprinted matter supplied under this service remains strictly Institution copyright and further copying, translation or processing of any kind is forbidden.
Copies cannot be supplied from publications where the copyright is vested other than in the Institution or where the material is unsuitable for copying. The Council of the Institution reserves the right to decline a request for copies, for whatever reason.
The Institution does not accept any responsibility for the quality of reproduction or stability of the copy or any other matter arising from the use of photography, cyclo-styling or other processes.

CHARGES

Letter-pressed or cyclo-styled reprints, when available, will be charged at a flat rate of 5s. 0d. per copy, plus postage.
In the case of items not available by these means, photographic copies can be supplied at a charge *per page* as follows:

Maximum size of original	*Charge per page (or part page)*
8×10 in	10d
8×13 in	1s. 0d

There is a minimum charge of 5s 0d per photo-copied item and postage is charged separately. An extra charge may be made where exceptional difficulties of photographic reproduction are encountered. Members and Affiliated Organizations of the Institution are eligible to be supplied with up to six items per annum free of charge and post free. Application must be made on the form for this purpose, available on request from

THE INSTITUTION OF AGRICULTURAL ENGINEERS
EDITORIAL UNIT 6 QUEEN SQUARE LONDON W.C.1.

Examination Board in Agricultural Engineering

1965 EXAMINATIONS

Final Examination for the National Diploma in Agricultural Engineering

Written papers may be taken *either* at the Essex Institute of Agriculture, Writtle, Chelmsford, Essex *or* at the West of Scotland Agricultural College, 6 Blythswood Square, Glasgow, C.2. on Tuesday, July 13th and subsequent days. Oral examinations will take place on Monday and/or Tuesday July 26th/27th *at the Essex Institute of Agriculture only.*

Institution Examination (for membership)

Written papers may be taken *either* at the Essex Institute of Agriculture, Writtle, Chelmsford, Essex *or* Rycotewood College, Thame, Oxon on Tuesday, July 13th and subsequent days. Oral examinations will be held on Monday and/or Tuesday 26th/27th July *at the Essex Institute of Agriculture only.*

Forms of application to sit either examination are obtainable from the Secretary, Examination Board in Agricultural Engineering 6, Queen Square, London, W.C.1. to whom completed forms must be returned by April 1st for the ND AGR E Final Examination, and May 1st for the Institution Examination. All correspondence concerning the examination should be addressed to the Examination Board and *not* to the examination centres.

PUBLICATIONS AND REVIEWS

Publications and Reviews will form a regular feature in the restyled *Journal*. The March and June issues will include reviews of books published in 1964 as well as those appearing in the current year.

Electricity in Agriculture;
by A. E. Canham:
Macdonald, London; 1964; 25s.

Mr Canham's book provides a welcome and comprehensive guide to the complex electrical equipment now to be found in use in commercial horticulture. He deals particularly with the principles and practice of the control of plant environment, both aerial and subterranean, with ventilation and shading, refrigeration and irrigation, control of daylength and supplementation of daylight. Other chapters discuss such subjects as electric motors and switchgear, electric wiring and maintenance of electrical equipment. The book is far from being merely a technical guide for electrical contractors as to the special conditions of horticultural applications of electrical equipment. It is written with deep practical appreciation of the practical horticultural aspects of the subject and its advice is supported by frequent reference to relevant research work. It will be of considerable value to growers as well as to all agricultural engineers who are in any way concerned with intensive horticulture. J.A.C.G.

Farm Machinery: Operation and Care;
by J. C. Turner, M I AGR E:
Cassell & Co. Ltd., London; 1964; 18s.

This is essentially a book for those who wish to understand the working principles and operation of farm machinery. It is specially written for students taking the examinations of the City and Guilds of London Institute and other examinations of similar standing. It will, however, be useful to students attending agricultural colleges and farm institutes and it is a handy reference book for farmers. The diagrams and other illustrations add to the value of this textbook. The author is to be congratulated on producing a publication that will be of great value to young people at the present time. A.H.

Irrigation: Its Profitable Use for Agricultural and Horticultural Crops;
by Sylvia Laverton:
Oxford University Press, London; 1964; 21s.

Although Mrs Laverton states that 'the engineering side of an irrigation scheme merits as much attention as its husbandry aspect' she provides only a brief survey of the types of irrigation equipment and pipework most applicable to farm irrigation. The value of the book lies much more in its comprehensive treatment of the husbandry aspects of irrigation in agricultural and horticultural practice and in discussion of its cost. Much information is brought together which will be of value to users of irrigation equipment and to those concerned with planning or advising on irrigation systems. An extensive bibliography and a helpful index are provided and there is a series of appendices which includes a glossary of irrigation terms and useful data on rainfall and transpiration as well as on factors such as pipe friction and sprinkler spacing. J.A.C.G.

PUBLICATIONS RECEIVED

British Diesel Engine Catalogue (Sixth Edition): *edited by D. S. D. Williams;* published for the British Internal Combustion Engine Manufacturers' Association by Temple Press Books Ltd, London; 1965.

British Standards 2659: 1964; Dimensions of Agricultural Cultivator Tines

British Standard 3417: Part 2: 1964; Specification for Agricultural Power Take-Off Shafts and Guards: Part 2, Single-Extension P.t.o. Shaft Lengths.

British Standard 3417: Part 3: 1964; Specification for Agricultural Power Take-Off Shafts and Guards: Part 3, Male and Female Shaft Yokes.

British Standard 3694: 1964; Specification for Dimensions of Frog for Tractor Plough with General Purpose Body (with Bolt-on Shares).

British Standard 3733: 1964; Specification for Endless V-Belt Drives for Agricultural Purposes.

Farm Electrification Handbook Number 9: Automatic Feeding—A Guide to the Practical Design of Installations: 1964.

International Institute for Land Reclamation and Improvement: Code of Practice for the Design of Open Watercourses and Ancillary Structures; Wageningen, the Netherlands; 1964.

All publications reviewed or listed above have been acquired for the Institution Library

Examination Board in Agricultural Engineering (1964–65)

Chairman
D. I. McLaren, BSC, NDA, MI AGR E, (*National Institute of Agricultural Engineering*)

Deputy Chairman
J. A. C. Gibb, MA, MSC, MASAE, MI AGR E, (*University of Reading*)

Ex Officio Members
President of the Institution of Agricultural Engineers
Chairman of the Membership Committee of the Institution of Agricultural Engineers

Other Members
D. R. Bomford, MI AGR E, (*Bomford Bros. Ltd.*)
C. A. Cameron Brown, BSC, MIEE, MI AGR E, (*Electricity Council*)
W. H. Cashmore, OBE, BA, NDA, CI MECH E, MI AGR E, (*Consultant*)
R. M. Chambers, BSC, B AGR, MI AGR E, (*Massey Ferguson Ltd.*)
Alexander Hay, NDA, NDD, HON MI AGR E, (*Association of Agriculture*)
J. Metcalfe, MBE, BSC, AMIEE, ASSOC I MECH E, (*N.W. Wilts Area College of Further Education*)
G. C. Mouat, BSC, ND AGR E, AMI AGR E, (*Essex Institute of Agriculture*)
J. E. Nicholson, OBE, TD, ACGI, MI AGR E, (*W. N. Nicholson & Sons Ltd.*)
P. C. J. Payne, BSC, MSC, PHD, MI AGR E, (*National College of Agricultural Engineering*)
C. J. Swan, BSC, NDA, NDD, ND AGR E, AMI AGR E, (*West of Scotland Agricultural College*)
J. O. Thomas, MSC, NDA, NDD, (*Lackham School of Agriculture*)
J. C. Turner, AMI AGR E, (*Rycotewood College*)
J. A. C. Williams, MSC, MI MECH E, FR AE S, AMI PROD E,
(*Chelsea College of Aeronautical & Automobile Engineering*)

A Representative of the Agricultural Engineers Association

A Representative of the Agricultural Machinery & Tractor Dealers Association

A Representative of the Royal Agricultural Society of England

Assessor Representing the Ministry of Agriculture, Fisheries & Food
C. Culpin, OBE, MA, DIP AGR (CANTAB), MI AGR E

Assessor Representing the Department of Education and Science
W. G. Lewis, HMI

Assessor Representing the Scottish Education Department and the Department of Agriculture & Fisheries for Scotland
J. A. Ferguson, HMI

Secretary
Miss J. P. Housley, BA

Training the Agricultural Engineer

THE NEW SCHEME

The careers now open to holders of the *National Diploma in Agricultural Engineering* are wide in scope and include most facets of manufacture and distribution—administration, field testing and development, machinery design, machinery installation, market research, technical sales representation, service representation—in all the major fields of agricultural engineering technology; agricultural machinery, farm building and equipment, rural electrification and soil and water conservation. ND AGR E holders also undertake official and educational appointments, in the Ministry of Agriculture, Fisheries & Food as Farm Mechanization Officers and Drainage & Water Supply Officers, as lecturers at agricultural colleges, farm institutes and technical colleges, and as scientific personnel at research and testing stations. They are also in demand overseas, both in commercially-operated and public undertakings.

It is confidently expected that the revised ND AGR E will continue to meet the demand for trained personnel for the above posts, and that the number of Diplomates qualifying each year will increase.

The ND AGR E courses in their revised form will continue to meet the needs of students whose existing training is in agriculture or engineering, and the courses will normally extend over one year's full-time study. The engineering-approach course will be available as hitherto to holders of Degrees or Diplomas in Engineering or Technology or of National Certificates/Diplomas in Engineering, and under the new scheme will also provide *a new avenue of opportunity* for further education for apprentices and other technicians who have obtained the City & Guilds 261 Certificate (Agricultural Engineering Technicians' Work). The Examination Board is currently reviewing the possibility of admitting students to the ND AGR E course who have obtained suitable qualifications other than those listed above whilst apprenticed to agricultural machinery manufacturers. The agricultural-approach course is expected to remain popular with holders of degrees in Agriculture or of the National Diploma in Agriculture. A minimum period of practical experience of work with an agricultural engineering firm or of mechanized farming will normally be required by the Examination Board. The minimum period may extend over twelve consecutive months full-time or be gained alternatively with attendance at a part-time or sandwich course, providing that the total period is equivalent to not less than twelve months full-time.

The ND AGR E syllabuses have been extended in the revised scheme to include the subjects of Horticultural Production & Environmental Control and of Business Studies. These will be available in addition to the existing optional subjects of Field Engineering and Farm Buildings & Mechanization. For the award of the ND AGR E candidates must qualify in *three* compulsory subjects and *one* optional subject. An important innovation, which is linked with the introduction of the new optional subjects, is that extra optional subjects may be taken as endorsement subjects. In this way Diplomates will have the facility of extending and diversifying *at any time* their agricultural engineering training in order to meet the requirements of posts in a constantly developing industry.

The Structure and Outline Syllabuses for the award of the National Diploma in Agricultural Engineering in 1966 and subsequently are available free of charge from the Secretary to the Board.

Obituary

Council records with regret the death of the following Members:

J. C. H. Lovelock, M I AGR E
F. C. Orchard, M I AGR E
E. Scott-Sissons, A M I AGR E
E. J. Woodhouse, A I AGR E
J. L. Young, A M I AGR E

Mr Orchard was a prominent member of the East Anglian Branch of the Institution, and had recently served on the Committee of that Branch. At the time of his death he was Manager of the Fens Sub-Area of Eastern Electricity.

AN INTER-BRANCH VISIT TO C.A.V. LTD

26th November 1964

WITH members drawn from the East Anglian, East Midlands and West Midlands Branches as well as from London and south-east England, a party of well over fifty assembled in Acton on 26 November 1964. The occasion was an Institutional visit to the Research and Engineering Headquarters of C.A.V. Ltd. During this whole-day tour, members were able to see special demonstrations and displays in connection with combustion research, fuel injection equipment and development and test facilities, vehicle electrical systems, fuel filtration, instrumentation for research and development, cold rooms and the metallurgical laboratory. The whole establishment is claimed to be one of the largest and most modern of its kind, with 84,500 sq ft of floor space. Within its four storeys it contains a machine shop for prototype manufacture, sound-proofed engine test cells, refrigerated chambers for low-temperature tests, a modern lecture theatre, library and photographic department.

Members were hospitably entertained to lunch at the Clarendon Restaurant, Hammersmith at which Mr R. G. C. Messervy, Director of Equipment Sales, welcomed the party and Mr W. J. Priest, President of the Institution moved a Vote of Thanks to the company for providing a day of such outstanding interest and pleasure.

A further visit to C.A.V. Ltd. is planned for 14 April 1965 to provide for the overflow of applicants who regrettably could not be included on the first occasion. Visits to other establishments are also planned for the future. One is to take place in November 1965 to Perkins Engines Ltd, Peterborough, of which further particulars will be announced in due course and which is again expected to be organized on an inter-Branch basis.

Pictured above are the members who took part in the visit to C.A.V. Ltd on 26 November 1964. The party was led by Mr W. J. Priest, President of the Institution, who can be seen in the centre of the front row (wearing the Presidential Badge of Office).

THE HANDLING OF MATERIALS IN UNIT LOADS IN AGRICULTURE AND HORTICULTURE

by J. B. HOLT, MSC (AGR ENG), MIMH, AMI AGR E*

Presented at an Open Meeting of the Institution in London on 28 January 1965

Introduction

For some time now it has been recognized that the majority of man and machine time on most farms is spent in materials handling[1] which is therefore a subject meriting serious attention by scientists of a wide variety of disciplines.

The problem is generally not simply one of how best to move a material from one site to another as it involves the questions of where the material is really required, in what form it should be moved and at what time in relation to operations which precede or follow. Having investigated these points there are often a number of distinctly different methods of loading and transporting involving a variety of containers, vehicles, machines or conveyors.

Harvesting and the Unit Load

Moving a crop, for example, potatoes, from a harvester to a store some distance away from the field involves a number of difficulties which may become more severe during the next few years. The rate of harvesting is increasing and further improvements are desired by many farmers. We may find that most of the farm labour force is involved in the actual harvesting, leaving few for handling. Since potatoes are susceptible to damage they must be handled carefully if they are not to suffer loss of value and this aspect is expected to become increasingly important.

With present harvesters, other than those involving bags, there is usually a transport vehicle running alongside the machine, so that increasing the carrying capacity of the transport vehicles is not the complete answer to the problem since at any time there must be one such vehicle alongside the harvester. Changing from loose bulk to large containers, of about 1 ton capacity, although it may offer advantages in other directions, does not in itself ease the transport and handling problem, since transport is still required to carry the boxes alongside the harvester while they are being filled. If however the harvester can be redesigned and built so that it can carry the box being filled in such a way that it can be placed on the ground out of the way of the machine in following bouts, a break will have been created between harvesting and handling. This break means that at no time need harvesting be held up by the transport or handling which, if performed by the type of vehicle to be described below, could in many cases take place in a relatively short time after the day's harvesting has been completed.

A convenient materials handling term for such a container of potatoes is 'a unit load' which for the present purposes can be taken to mean a box pallet, box, bin or other container, a pallet or other base loaded with a number of bags or bales of material or a group of, say, bales handled together so that the weight of the loaded container or assembly is between perhaps 5 cwt and 30 cwt. A unit load is therefore of such a size that it is not suitable for handling manually but is suitable for handling, for example, by means of a fork-lift attachment on a tractor. Examples of common unit loads are 43 in. × 43 in. pallets loaded with 24 bushel boxes of apples, 6 cwt capacity bulk bins—usually box pallets—of fruit, bags of fertilizer or feeding stuffs on pallets and 2000 lb capacity box pallets of potatoes.

Equipment available

The equipment used to handle these loads in the field and around agricultural buildings is generally a tractor with a fork-lift attachment on the rear or, for the lighter loads only, an attachment working at the front of the tractor. The rear-mounted attachment is a mast unit with its own hydraulic lift ram similar to that of an industrial fork-lift truck, or for the lighter loads it may be a pair of forks attached to members carried on and lifted by the tractor's 3-point linkage. The loading device at the front may be of the mast type or may be a pair of forks carried on a front loader incorporating a parallel linkage. If the transport distance is short the load may be carried on the tractor but, with the exception of certain small loads on the rear, this is illegal on public roads. Generally therefore the unit loads should be transported on tractor-drawn trailers being loaded and unloaded by tractor-mounted lifting equipment.

Potatoes, for example, may be stored in box pallets stacked three high in insulated buildings by a tractor with rear-mounted fork-lift attachment. The handling difficulties here are due to the relatively clumsy nature of the tractor compared with its industrial fork-lift counterpart, the driver having to look over his shoulder to see his work and lean sideways to look along the side of the load to position it accurately. The rather flimsy nature of the containers, which due to their use only once per season are designed to be made as cheaply as possible, adds to

* Harvesting and Handling Dept; National Institute of Agricultural Engineering

the driver's difficulties in doing this work, which in any case is only a part-time occupation.

Improvement to Fork-Lift Equipment

In an attempt to improve on the existing equipment and methods an experimental linkage has been devised at the N.I.A.E. to carry a normal mast type of fork-lift at the rear of a conventional tractor. Various members of the linkage consist of hydraulic rams, the control valves of which are operated by the movement of a 'joystick' in the appropriate direction to give the mast a sideways, slewing or fore-and-aft tilting motion. First trials have been most promising, the equipment enabling the driver to position the tractor approximately relative to the desired position of the load and then adjust the position of the mast and lower the forks.

Some experiments[2] were carried out with an experimental reversible tractor fitted with a mast type of fork-lift attachment at its driven wheels end. A series of handling tasks by drivers sitting facing the forks and also sitting with their backs to the forks showed the advantages of a man facing his work. It also emphasized the importance of easy control over the movement of the tractor and operation of the lift unit.

An amalgamation of a reversed or reversible tractor fitted with power-assisted steering and a mast provided with relative movement operated by a simple control would therefore seem to be an obvious improvement.

The transmission and its control on tractors or other machines performing loading work, which invariably involves much shunting to and fro, merits special consideration. In an experiment comparing tractors fitted with hydrostatic or mechanical transmissions performing front loader work handling 5 cwt capacity boxes,[3] it was found that the advantage of a hydrostatic transmission lay in the more convenient handling characteristics, particularly if the transmission was controlled by a foot pedal. With fast working cycles one hand was almost constantly in use on the hydraulic controls of the front loader, and the full benefit of the hydrostatic drive—fast reversals and accelerations and accurate positioning—was obtained entirely by foot control.

The agricultural tractor is, however, too large and clumsy a machine to be used in normal fruit stores—cold or gas—so one of the smaller types of battery or gas-powered industrial fork-lift trucks is more suitable despite its use being limited to work on a flat concrete or similar surface.

An experiment designed to investigate the advantages and disadvantages of four different types of fork-lift machines and an agricultural tractor with a rear fork-lift attachment produced some interesting results.[4] A sequence of tasks involving accurate placing, stacking and movement of ballasted well-based and pallet-based bins within a working area about 36ft × 36ft showed that there was not a lot gained by the more elaborate and expensive rider-operated fork-lift truck over a pedestrian-controlled machine. The straddle truck was in some ways easier to operate because of its different steering characteristics due to the non-steered wheels being approximately under the tips of the forks. A machine of this type is particularly suitable for handling well-based bins, which provide adequate space under their shoulders for the stabilizing arms and wheels, since the space required for manoeuvring is less than that required with a counter-balanced fork-lift truck.

The pulse rate of the driver was considerably higher after performing the tasks with the tractor than it was after using the other machines, indicating the greater physical effort required for a rate of work which was lower than that for the other self-propelled machines.

A considerable amount of space around a lorry or trailer is required to load or unload it from the sides with unit loads, especially by means of tractor-mounted equipment. Where adequate space is not available the practice is to deal with one side first and then turn or move the vehicle so that the other side is accessible. This wastes time and may be dangerous owing to the one-sided load on the vehicle while it is being moved. If the loading area is not really flat the operation of placing a 'tight' load on the lorry is particularly difficult especially if a side shift is not available.

Evolution of the Self-Loading Vehicle

The handling of unit loads between field and store tends to involve a number of men and machines and if a steady flow is required and for good man and machine utilization the team needs careful balancing and supervision.

It was for these reasons that the Materials Handling Section at the N.I.A.E. devised a vehicle which makes the loading, transport, unloading and stacking of unit loads a one-man, one-machine task. The self-loading vehicle,[5] as it has been called, is basically a self-propelled transport vehicle with a loading device at one end and a powered conveyor system to transfer unit loads along the length of the machine. A family of different types has been devised but so far only two experimental machines have been constructed, the first a two-ton capacity exploratory machine and the second a low-chassis machine[6] designed for investigating the techniques involved in the use of such a method of bin handling in orchards, as shown in Fig. 1.

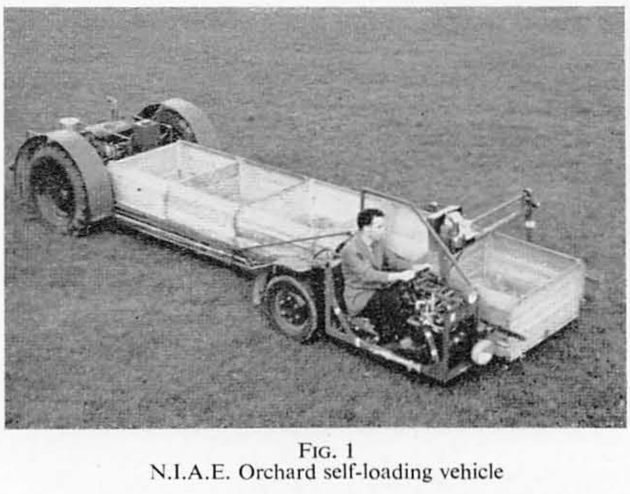


FIG. 1
N.I.A.E. Orchard self-loading vehicle

It has been found that it is a quick and simple matter to pick up unit loads from the ground with this type of machine; for example, with the second vehicle the time taken to pick up five bins spaced along an inter-tree roadway in an orchard is about 1.7 min. It follows that if an agricultural crop were being handled by a self-loading vehicle of suitable size there would be no objection to boxes or bins filled during the harvesting operation being placed on the ground. Transport need no longer keep pace with a harvesting operation.

To be an economical success the vehicle would have to be the principal piece of equipment in a complete handling system based largely on the unit load method of handling, although there would be nothing to prevent the vehicle loading on to itself a conventional form of trailer, lorry or muck-spreader body should this be required. Being designed as a transport vehicle rather than the maid-of-all-work which the tractor has become, it is possible to fit it with suitable wheel equipment and suspension to give a higher average transport speed than is possible with a tractor and trailer, without damaging the material being carried. The shock loadings recorded in a recent experiment carried out in conjunction with the Damage Assessment Section at the N.I.A.E. show the great difference between various types of suspension and wheel equipment. '*g*' meters were fitted to a well-based bin holding about 8 cwt of potatoes which was transported, with other bins of ballast where appropriate, along a level tarmac road and over an obstruction 2 in. high and 18 in. in length. The table shows the merit of the independent suspension of the front wheels of the orchard self-loading vehicle.

Handling of Apples in Bulk Bins

The traditional small containers used for the handling and storage of apples, usually trays, or bushel boxes, required a considerable amount of labour when they were loaded individually onto trailers, and where the fruit was in contact with the wood it was liable to be marked. Palletising these containers can save 33% of the labour during the laying out of the empties in the orchard, and 56% if the filled boxes are transported and stacked in the cold store on the same pallets.[7] The use of bulk bins holding about six cwt of apples, in place of the bushel boxes and pallets, eliminates the manual stacking of the small boxes on the pallet, costs less per unit capacity, forms a more stable load on transport, and saves store volume. Provided the bin depth is not excessive the total damage is usually less since a smaller proportion of the fruit is in contact with timber.

The use of bulk bins in orchards in some ways increases the load on management since the bins are too large and heavy to be moved by the pickers if they have not been placed conveniently; however, an important saving in pickers' time is usually obtained. Where the crop is light for any reason the use of bins can result in too much of the pickers' time being spent in walking.

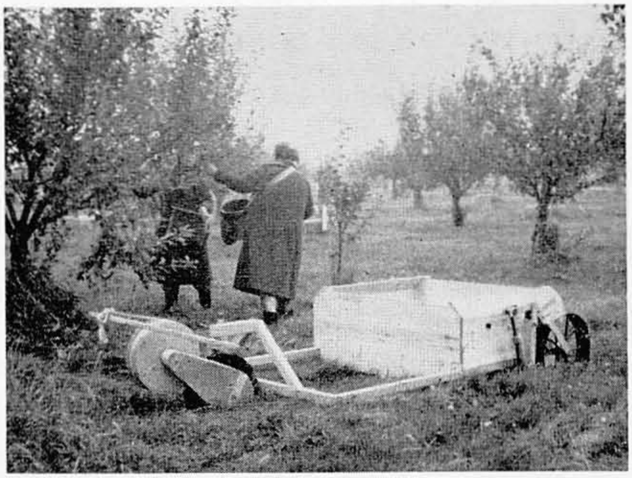


FIG. 2
N.I.A.E. Orchard Pallet truck

A tractor with carrying forks on the rear can be used to move the bins from time to time but this is rather extravagant. An alternative solution might result from an experimental orchard pallet truck shown in Fig. 2 devised by the N.I.A.E.[8] which enables a group of pickers to move a bin through the orchard as required while they fill it, and then when full to lower it to the ground to await powered transport.

TABLE SHOWING VERTICAL ACCELERATION UPWARDS OF AN 8 CWT BIN OF POTATOES TRANSPORTED OVER AN OBSTRUCTION

Transport Vehicle	*Springs*	*Tyre Pressure lb/in²*		*Upwards Vertical Accelerating 'g' (Static=o) Speed mile/h*					
		Front	*Rear*	2	4	8	13	20	22
1st Self-Loading Vehicle	Leaf Front and Rear	35	35	.5	.5	.5	.5	1.0	1.0
Orchard Self-Loading Vehicle	Ind. Coil Front No Rear	35	14	.5	1.0	1.0	1.0	1.0	.5
Tractor with Fork-Lift	Non	48	20	—	4.5	11.5	—	—	—
Tractor and 2-Wheel Trailer	Non	27, 12, 48		—	4.5	11.0	—	—	—
Tractor and 4-Wheel Trailer	Non	17, 12, 48, 48		1.5	6.0	—	—	—	—

The normal commercial methods of transporting bins from the point where they are filled with fruit to a nearby store use tractor-mounted carrying forks. For longer distances tractors and trailers, or quite frequently, lorries are used, these being loaded in the orchard by tractor-mounted equipment and unloaded at the store by a small industrial-type fork-lift truck.

Work in six orchards in 1964 with the experimental orchard self-loading vehicle has shown that with it one man can load, transport and unload bins at a greater rate than the other methods employing a number of men and machines. A feature of the transport of fruit at harvest time is the distances involved; it seems to be quite normal for fruit to be moved between two and, say, eight miles from the orchard to the store. The higher transport speeds possible with the sprung self-loading vehicle as compared with tractors and trailers is of course a great advantage here. To carry a greater payload on a long haul a version with an upper deck is suggested, with possibly a matching double-decked trailer for travel on the road.[6]

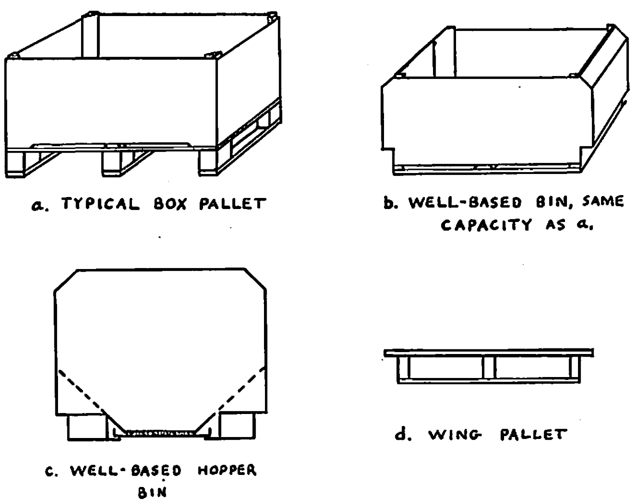


FIG. 3
Containers

The experimental machine was designed to handle the well-based bin, as shown in Fig. 3b, which wastes considerably less store volume than the conventional box pallet and is easy to pick up off uneven ground with special forks which support the bin under its shoulders. The actual construction and dimensions of the bin can be varied to suit the requirements and the plan dimensions may, if required, be similar to those of B.S. pallets. For fruit we have had experience of using 40 in.×48 in., 43 in.×43 in. and 60 in.×36 in. versions, all of 21 in. internal depth.

A leader-cable system to guide transport vehicles between the field and the store without the services of a driver[9] could be worthwhile in some circumstances and might be especially suitable within an orchard where the pattern of movement is fixed by the rows of trees. In the orchard the leader-cable system might be applied to the guidance not only of transport vehicles but mobile picking platforms and spraying and grass-cutting machinery, thus spreading the capital cost of the installation.

A Broad Approach to Materials Handling

The importance of examining the complete system when considering a particular handling problem cannot be over-emphasized. A satisfactory solution to the handling of bulk bins of fruit from the point of picking to the cold store, for example, may not result in bins coming into general use if similar attention is not also given to problems created for the smaller fruit grower by their introduction. Mention has already been made of the orchard pallet truck, but at the other end of the operation there is the problem of getting the fruit out of the bins with minimum labour and little damage. The N.I.A.E. has therefore found it necessary to pay attention to the water flotation method of removing fruit from the bin.

It is when the mechanization of handling and transport is viewed in relation to the complete operation that it is often found that major changes should be made to equipment and methods involved before or after the handling operation. The example of the potato harvester being modified to carry boxes has already been cited. Further examples are a combine-harvester similarly modified to enable unit load handling to be exploited, and the combined drill. In recent years there has been a move away from the combined drill to the seed drill and separate fertilizer broadcaster. This move in most cases has been brought about by the time taken to man-handle the seed and fertilizer into the combined drill. Problems such as fertilizer not flowing in damp morning conditions also have played a part. However, if there is no desire to apply the seed and fertilizer at different times it seems to be wrong from a handling point of view to run over the land twice with two sets of equipment. The problem involves the design of a combined drill or the combination of a drill and some form of spinner spreader that can be rapidly reloaded with seed and fertilizer by mechanical means. For this the conventional long rectangular hoppers are unsuitable and one possibility is a central divided hopper, feeding the material across the full width of the machine by means of conveyors, which could be filled rapidly from divided bins carried on a self-loading vehicle or other machinery, or could be replaced when nearly empty by fresh hoppers.

When the equipment and facilities are available on a farm for handling the main material associated with one particular enterprise in unit loads, the economics of handling a very wide range of materials, and probably all the materials on that farm, in the form of unit loads become favourable. For example at the moment about half of the combines in this country are still of the bagger type with their associated handling work. The alternative tanker combine with its bulk transport, usually tipping trailers with grain-tight bodies, is regarded as fairly efficient. However if a self-loading vehicle were available on a particular farm, a combine filling, say, 1 ton capacity containers would have some advantages. A system along these lines has been in use in Norway for some years.[10] The higher output combines which are likely to come into use will increase the existing transport problems and the slow trend towards the amalgamation of farms with common grain storage facilities increases the average transport distance. There is the possibility of drying grain in the containers and also of storing it in them in a light-framed building. The cost per ton capacity would be less than that of a silo installation with intake pit and conveyor system, and the container method would provide the answer to the merchants' constant request for a higher rate of loading of the transport which they send to collect the grain.

It has been said, using the term 'bulk' to mean 'not sacks', that the 'trend from sacks to bulk will be accelerated, and will move completely to bulk. One can see box pallets or stillages being used in a big way on the small and medium farms in conjunction with the tanker combine. Pallets and stillages, it is thought, will be hired out by our present sack contractors.'[11]

For many purposes in agriculture and horticulture the container can be used once only per year, e.g. apples or potatoes being harvested into and stored in a container. This means that the construction and cost should be very different from that of its industrial counterpart which may be used in a weekly cycle. However, containers could be used repeatedly for handling some feeding stuffs which involve a considerable amount of handling, for example the weight of compounds produced in Great Britain during 1961 was 8 million tons.[12] For the relatively short haul work from the mills of the 1,200 compounders to farms a road version of the self-loading vehicle would be ideal, unloading unit loads which could be bins or palletized bags of feeding stuff at the farm without farm assistance. Fertilizer could be handled in a similar way.

The Scope of Unit Loads

The scope of the unit load system of handling on farms is considerable and might be summarized as follows:

1. Potatoes
    (a) transport between field and store
    (b) transport and storage
    (c) transport and storage followed by transport to grading or processing plant.
2. Grain
    (a) transport from field to store
    (b) transport and drying
    (c) transport, drying and storage
    (d) transport, drying and storage and transport to merchant.
3. Fertilizer
    (a) transport from merchant to farm
    (b) transport to farm and storage
    (c) transport to farm, storage and transport to field
    (d) farm storage and transport to field.
4. Seed corn as 3a, b, c, d.
5. Seed corn and fertilizer in divided containers from farm buildings to field.
6. Milk in tanks with suitable bases or in churns on pallets
    (a) from farm dairy to collection point
    (b) from farm dairy to bulk depot.
7. Farmyard manure in containers or tanks—advantages in cleaning out loose boxes and small breeding units.
8. Transporting small animals such as pigs, sheep and calves which could be loaded at ground level.
9. Sugar beet held for short period, saving cost of concrete slab and providing rapid loading of road transport.
10. Many horticultural crops grown on a field scale such as carrots, celery, red beet, cabbage, peas.
11. Hay and straw in groups of conventional bales or perhaps in larger bales
    (a) from field to store
    (b) from store to point where required for feed or bedding
    (c) for loading and transporting off farm.
12. Apples and pears
    (a) transport from orchard to pack house
    (b) transport from orchard to cold or gas store and to pack house
    (c) transport from pack house to retailer.
13. Feeding stuffs from farm store to livestock and as 3a, b,

Container Design

This variety of handling operations demands a variety of types of containers or bases but for use within one business enterprise they should have certain common physical characteristics to make them acceptable to one range of equipment.

The author believes it is more important at this stage in the development of materials handling in agriculture and horticulture that the container should suit the requirements of the operation rather than conform to some standard design or dimensions which have perhaps been found suitable for industrial purposes, [13] [14] or for transporting by rail, air or sea. While it is obviously important, if the containers may at some time leave the owner's premises, to ensure that they can be handled with conventional equipment without difficulty, the precise dimensions and shape may not be so critical. A fork-lift truck with normal forks can handle a number of different sizes of pallets conforming to B.S.2629:1960, the critical factors being the weight of the load and distance of its centre of gravity away from the mast. The well-based bin was originally designed to suit the handling of fruit both in the orchard and in cold stores. Even where the saving in overall volume is of little importance the design offers advantages by providing a flat base for standing on soft ground, pick-up shoulders which guide the lift-forks into position without fouling any parts of the box, more stable loads when a given number of containers are stacked on top of each other, due to their relatively lower height, and a saving in timber and hence money due to the elimination of the normal pallet base.

When considering the design and construction of a container the frequency of use, the desired life, weight, dual-purpose characteristics and standardization must be balanced against price and the economics of the operation. Fig. 3 shows a container of the British Standard box pallet type, a well-based bin and a hopper bin of the same outline which economizes in height. The wing pallet can be handled by the special forks used with the well-based bins or with normal forks and can be employed as an adaptor base should this be necessary.

In the interests of economy many pallets used in horticulture and agriculture have shallower bases than those recommended in B.S.2629:1960 despite the fact that the working conditions are more difficult than the industrial ones for which the B.S. pallets are intended.

REFERENCES

1. GIBB, J. A. C.; 'The Mechanical Handling of Farm Materials', *Jnl. Inst. of Agr. Engineers, XVII, No.* 1, 1961.
2. HOLT, J. B., BULL, D. A., WOLF, J. S.; 'An investigation of reversible travel for tractors. II: Handling and Transport.' *J. agric. Engng Res.*, 1964 9(4).
3. NATION, H. J.; 'Some pilot field comparisons between tractors fitted with hydrostatic or mechanical transmissions' *J. Agric. Engng. Res.*, 1963 8(4)355.
4. HOLT, J. B., BULL, D. A.; 'A comparison of 5 types of fork-lift machine' to be published in *J. Agric. Engng. Res.*
5. HOLT, J. B.,; 'Experimental Self-loading Vehicle' *J. Agric. Engng. Res.*, 1963 8(1)3.
6. HOLT, J. B., BULL, D. A.; 'The use of a Self-loading Vehicle for Handling Fruit' to be published in *J. Agric. Engng. Res.*
7. DEVINE, E. S.; 'Fruit Handling: The Movement of Empty and Full Containers at Harvest Time' *J. Agric. Engng. Res.*, 1962 7(4)354.
8. Annual Report N.I.A.E. 1962-63 C.2.4. Pg 60.
9. MORGAN, K. E.; 'The Agricultural Tractor—Some Unorthodox Concepts' *Jnl. Inst. Agr. Engineers, XX, No.* 2, 1964.
10. GIBB, J. A. C.; 'The Mechanical Handling of Farm Materials' (discussion) *Jnl. Inst. of Agr. Engineers XVII, No.* 1, 1961.
11. CULL, R.; 'Aspects of Material Handling as it affects the Agricultural Merchant'. Paper presented at conference of National Association of Agricultural Contractors 1962.
12. BIRD, D.; 'Bulk Handling of Feeding Stuffs' Paper at above conference.
13. Pallets for materials handling suitable for transport by road and rail. Brit. Stand. Spec. 2629:1955.
14. Specification for Pallets for Materials Handling for through transit. Brit. Stand. Spec. 2629:1960.

DISCUSSION

MR G. C. MOUAT (Department of Agricultural Engineering, Essex Institute of Agriculture) said that while the vehicle Mr Holt had described might be excellent for use in orchards it was obviously not suitable for carrying potatoes off potato fields in a bad autumn. He asked what differences Mr Holt envisaged in a handling vehicle designed for agricultural rather than horticultural purposes.

Mr Mouat went on to say that the form of package employed for agricultural materials often created difficulties. The hay bale was neither big enough for some handling techniques nor small enough for others. What was wanted was either wafers, which could be handled mechanically much more easily than conventional bales, or alternatively a very much bigger bale which could provide a satisfactory load for mechanical handling equipment. Such a load could consist of a single bale or of a number of conventional bales formed into a single package. In the second case eventual splitting of the package for use would be easily done.

Mr Holt agreed that the existing bale was of an unfortunate size and shape—too small for individual mechanical handling and too large for quick and easy manual handling; nor did it lend itself naturally to feeding and bedding of livestock. Because there were certain technical difficulties in making wafers from grass in Britain Mr Holt felt that the larger unit might be the better answer. Some work had been done on the making of 10 cwt bales and he thought it would be quite possible to form bales of this size in such a way that spaces were left for the tines of a fork-lift device to enter. With high-density bales a hole through the centre could be left to facilitate drying and conditioning. The trend of development might move either in this direction or towards strapping groups of separate high-density bales into single units, as Mr Mouat had suggested.

The orchard self-loading vehicle was suitable only for the purposes for which it had been designed. Important features for work in agriculture included ground clearance, adequate power, wheel equipment, etc. (Mr Holt then showed some slides illustrating agricultural applications of self-loading vehicles).

MR I. CONSTANTINESCO (Food and Agriculture Organization, East Pakistan) said that the applications to overseas crops of the equipment Mr Holt had described was of great interest—especially for coffee. A coffee plantation was virtually a very large orchard, but the trees were closer together and the self-loading vehicle would require a narrower wheelbase than that described. He was sure it would be of interest to all plantation workers overseas and particularly in East Africa.

The handling of sisal was another problem that had confronted growers for many years. The transportation of many thousands of tons of sisal leaves from field to factory would have to be based on some form of container. The leaves would be cut from the plants and placed in the containers, which would then be taken to the ends of the rows for loading onto lorries or on to a railway. The containers would have to be designed to suit the shape of the sisal leaf and to have adequate depth, and a large number of containers would be needed. The problems needed further investigation.

Mr Holt said that he was interested in these remarks, but that there might be difficulties in constructing a very narrow self-loading vehicle. Mr Constantinesco added that in the case of sisal there was ample headroom. A coffee tree, on the other hand, was like a small apple tree and could almost cover the inter-row spaces, so that headroom was very restricted.

MR P. G. FINN-KELCEY (Consultant) mentioned Mr Holt's reference to damage when handling apples, due to contact with the sides and base of the crate and to unloading crates in bulk. He had seen examples of soft fruit handling in plastic lined containers, which had reduced the incidence of damage to a crop more delicate than either apples or potatoes to negligible proportions. Damage due to contact between fruit and fruit was now more important than that due to contact with the sides of the bins.

Mr Finn-Kelcey was not convinced that the use of a leader-cable system of automatic tractor control for transport from orchard to store was desirable. The labour requirement of transport outside the orchard was small compared with that within the orchard, for spraying, grass-cutting and other orchard operations. Pruning had not been mentioned, and he believed this was probably the operation which had the highest labour demand of all. A mobile picking platform could also be a mobile pruning platform, and a leader-cable guidance system for such a machine should be easily arranged. The hedge systems of tree planting and pruning now being adopted in America were easy to pick and prune from platforms.

For hay handling, Mr Finn-Kelcey thought that it would continue to be necessary to use bales, perhaps of slightly larger size than at present, but that eventually the hay would have to be pelleted in order to facilitate feeding and transport between farms or merchants. The fourfold increase in density of hay pellets, compared with bales, would result in enormous savings in handling bulk. His own view was that hay should be produced and pelleted by specialist growers in the drier parts of the country and then sold to hay users elsewhere. This could be done under existing conditions, but mobile machines, pelleting in the field were ruled out. The pelleting machines had a power requirement of 140-150 hp and was unlikely to be suitable for field work in inclement weather. The sequence of operations would therefore be to bale the hay in the field, transport it to the barn, dry it as necessary and pellet it for use or transport.

Mr Holt replied that the N.I.A.E. was very interested in the possibility of lining bins and containers, which Mr Green's paper would probably mention. In bins 21 inches deep, although there was comparatively little pressure against the bottom of the container it was the bottom layer which showed signs of pressure damage. If the bin bottom had a liner which supported the fruit better than a flat surface—as an egg cup supported an egg—there seemed to be no reason why deeper bins could not be used without the apples being damaged. From the handling point of view the existing 6 cwt bins were rather small and did not differ sufficiently from bushel boxes. Liners might therefore be very helpful in increasing the practicable size of bins.

Regarding the leader-cable system of tractor guidance, Mr Holt agreed that it was unlikely to be economically justifiable simply to guide loaded transport vehicles from orchard to store. If it could be justified for other operations it would also be an attractive possibility for guiding transport vehicles. At the present time the permanent farm staff were usually very fully occupied in driving tractors to and from the store. If they could be released from these tasks to supervise the casual pickers and help to minimise damage, quite extensive capital expenditure might be warranted. Leader-cable systems could certainly be used to guide mobile picking platforms. Mr Holt had seen a picking system in pyramid orchards in England in which two or three trailers were pulled very slowly down the rows behind an ordinary vineyard tractor. Eight women work from the trailers, the first having a platform about 18 inches above ground level, with higher platforms on the succeeding trailers. In this system the tractor-driver did virtually no useful work; with a guidance system the power unit could be controlled by simple stop/start and slow/fast controls on the picking platform.

Mr Holt agreed with Mr Kinn-Kelcey's remarks on hay handling and added that if hay were to be produced by specialist growers high-density handling methods such as pelleting would become very much more important.

Mr W. A. Hayles (Farmer) asked for further information on the possibility of drying grain in boxes, and on the possible use of such boxes for other purposes as well. He also asked about the rates of loading which could be achieved with boxed grain and whether this implied tipping the boxes directly into a bulk vehicle or using a conveyor of some kind. Mr Holt said that he regarded the box as a form of tray drier which might be attractive in parts of the country where storage on the floor was unsuitable. He understood that grain had been dried successfully on the Continent in boxes with bottoms of either perforated metal or perforated hardboard, which were placed over apertures in a drying floor rather as in drying sacks on a platform drier.

Another possibility also required perforated bottoms, but made use of air blown downwards through the containers, which were covered over and connected to an air manifold. It might be easier to obtain a good seal round the top of a container than by locating the base over an aperture in the floor. Such systems would not appeal to the larger grain producer, but might suit the many small grain growers. The multiple use of boxes—for potatoes or fertiliser as well as grain—depended on the length of storage period envisaged. The grain storage period might clash with the potato harvest. If fertiliser were to be stored in the boxes it would be important to ensure that it could be used before the containers were required for some other material.

The high rates of loading he had referred to were obtained with hopper-bottomed containers and could be achieved with a tippler mechanism forming part of the loader on a self-loading vehicle. Hopper bottoms were more expensive than flat bottoms. If grain were to be stored in boxes they must be as cheap as possible and hopper-bottomed containers would not be suitable for that purpose. A smaller number of containers—equal to at least a day's combining—used merely for transporting grain from field to store, could be fitted with hopper bottoms with advantage. They could also provide a rapid means of filling bulk lorries when grain was sent off the farm—provided a lifting machine was available to discharge them into the road vehicle.

BRANCH HONORARY SECRETARIES

EAST ANGLIAN

J. B. MOTT, AI AGR E
County Education Offices
Stracey Road, Norwich, Norfolk

EAST MIDLANDS

R. D. S. BARBER, BSC, ND AGR E, AMI AGR E
The Farm Institute
Caythorpe Court, Nr Grantham, Lincs

NORTHERN

H. B. HUNTLEY, M I AGRE
4 Southwood Gardens
Gosforth
Newcastle-upon-Tyne 3

SCOTTISH

J. WEIR, BSC, A M I AGR E
North of Scotland Hydro-Electric Board
16 Rothesay Terrace, Edinburgh 3

SOUTH WESTERN

J. B. PATERSON, NDA, AM I AGR E
Seale-Hayne Agricultural College
Newton Abbot, Devon

WESTERN

H. CATLING, ND AGR E, AM I AGR E
Engineering Dept
Royal Agric. College, Cirencester, Glos

WEST MIDLANDS

K. M. THOMAS, GRADUATE I AGR E
41 Birches Park Road,
Codsall,
Staffs

YORKSHIRE

T. H. E. HARRISON, BSC(AGRIC), MSC(AGRIC ENG), GRADUATE I AGR E
16 Wood Lane, Ashenhurst
Huddersfield, Yorks

WORK STUDY IN THE MECHANIZATION OF FARMING

by R. B. HALL *

Presented at an Open Meeting of the Institution in London on 28 January 1965

by A. J. EDWARDS †

SUMMARY

1. *Some of the techniques of work study have been useful in assessing the economics of agricultural mechanization.*

2. *In maincrop potato harvesting production studies have revealed the labour requirements of the different systems. The hand-picking cost is not related to the number of picker hours but depends upon the type of labour employed. Thus the worthwhileness of a harvester depends mainly upon the actual piecework picking cost that the farmer has to pay.*

3. *In early potato harvesting production studies have shown a saving in the region of 30 worker hours per acre by using a complete harvester. From this the economics of using a harvester can be judged.*

4. *In the harvesting of vining peas using a static viner, critical examination of all the operations involved has indicated possible ways of reducing the total labour force needed. On many farms this can result in a smaller regular farm labour force and hence quite high capital expenditure may be warranted.*

INTRODUCTION

Some agricultural engineers appear to be dedicated to the policy of replacing men by machines. At times this policy may be pursued almost without regard to the economics of the situation. But machines should pay their way, otherwise they are not being used to the best economic advantage.

As a Work Study Officer attached to the National Agricultural Advisory Service (N.A.A.S.) Regional Farm Management Department at Cambridge, my job has been to discover what are the present-day work rates and gang sizes for various farming operations. This information has been needed for farm planning purposes and it has shown the economics of some types of mechanization.

With the present-day organization of cereal harvesting and the rapid spread of one-man sugar beet harvesting systems, two main labour peaks remain in arable farming. These are the harvesting of vining peas and the harvesting of both early and maincrop potatoes. These three tasks comprise many aspects of materials handling. In the following sections these jobs are examined from a work study point of view.

THE USE OF COMPLETE HARVESTERS FOR MAINCROP POTATOES

During the last 5 years production studies have been carried out by N.A.A.S. Work Study Officers on potato harvesting prior to storage. Two main systems of hand picking have been observed as well as complete harvesters. These hand-picking systems are:

(*a*) The Breadth System

In this system several rows are lifted before picking starts. The pickers work down the rows together, picking into baskets and tipping each basket as soon as it is filled. Tipping is usually into a trailer or cart travelling with the team but boxes mounted on a tractor or boxes stood every few yards at the side of the rows may be used. Good teams work in an arc around the trailer and walking with the baskets is reduced to a minimum. Normally when women pickers are employed extra men (1 to each 4 to 6 women) are needed to tip the baskets. Unless the pickers help each other the speed of the gang is that of the slowest picker. This method is unsurpassed for the collection of harrowings after the main lifting.

(*b*) Stint Systems

There are two common types of Stint systems. These are:

1. *The 'Fen' System or 'Stint to Basket' System*

Each picker has an allocated stint. The potatoes are picked into small baskets (holding 25-35 lb). These are left in the row when full and male 'teamers' tip them into trailers (or carts) after each row has been picked. The pickers cross over the undug rows, picking alternate rows each side. In this system with spinners or 1-row diggers the digger is often waiting for the teamers to finish, the teamers sometimes waiting for the pickers to finish and the pickers usually waiting for the digger. The 'teaming' is usually the critical operation. By using a 2-row digger the delays to the digger can be avoided.

2. *Stint to Box Systems*

The pickers have allocated stints (which may not be rigidly adhered to). They empty their baskets into pallet

---

* Formerly of National Agricultural Advisory Service, Ministry of Agriculture, Fisheries & Food, and more recently Farm Economics Branch, Agricultural Extension Service, Queensland, Australia.

† N.A.A.S, Nottingham Division, Ministry of Agriculture, and Food.

boxes (usually 5 or 10 cwt). These boxes are moved on the foreloader or rear linkage of a tractor. They may be tipped into trailers or lorries in the field or taken to the clamp or store and tipped there.

Labour Requirements

The first investigations showed that although there was a wide range of performances for each system the labour requirements for the Breadth system were much lower on average than the others. The first observations showed labour requirements in hours per acre as follows.

TABLE 1

	Breadth	*Stint to Basket*	*Stint to Box*	*Complete Harvester*
	h/ac	h/ac	h/ac	h/ac
Observed Range	22-30	38-50	35-60	30-40
Average (of 'good' systems)	25	45	45	35

The superiority of the Breadth system may be due in part to the quality of the labour used. It is very difficult to compare labour requirements if in one case the workers are professional gangs of male pickers and in the other groups of housewives, accompanied by young children out for a 'social get-together' in the potato fields. As more information became available (in succeeding years) examples were recorded of Breadth systems which used up to 47 worker hours per acre. In Yorkshire observations were made in 1963 on two farms which were using the Breadth system for the first time. In each case less labour was required than 1962. Unfortunately other changes—change of variety from Majestic to Record and change from daywork to a bonus system—meant that accurate comparisons were impossible. Nevertheless it seemed at this time, that the picking could be speeded up if a Breadth system were used.

At this stage it seems worthwhile to stop and enquire what factors affect the farmer in his choice of harvesting method.

1. There is a limited season available for harvesting and the farmer will reject any method which will not get the crop cleared in the time available. This factor ruled out the use of a complete harvester on some farms where picking must proceed at not less than 3 acres per day and when one harvester could only manage two acres per day.

The next three important factors are as follows:

2. To use as little regular labour as possible.
3. To keep the direct cost of harvesting as low as possible.
4. To minimize damage to the potatoes.

The extent to which a farmer can achieve any one of these aims will be affected by the availability and quality of both regular and casual labour.

1. *Rate of Work*

The figures available show that the rates of work shown in Table II are attained in practice with reasonably well organized systems.

The number of pickers can be varied in both the Breadth and the Stint to Basket systems. The result, in having a larger 'non-picking' (or regular) gang, may be less efficient than with the basic team. With Box systems much more flexible arrangements can be made. The regular team can be made up of from 2 to 5 (or more) men who could be organized as follows:

2-Man Team	1 man on digger, 1 with foreloader emptying boxes into trailer or loading boxes onto trailer and taking trailer to store.
3-Man Team	1 man on digger, 1 with foreloader loading spare trailer, 1 man driving other trailer to store.
4-Man Team	As 3-man team but with 1 extra man full-time at store or with one man on each tractor and trailer.
5-Man Team	1 man on digger, 1 with foreloader, 1 man on tractor and trailer being loaded, 1 man driving to store and 1 man at store.

From these figures the farmer can rule out methods which are too slow for his requirements.

2. *Requirement of 'Non-Picking' (or Regular) Labour*

There was found to be far less variation in the amount of 'non-picking' labour used per acre than in the total labour. Reasonably well organized systems were found to be as follows:

Complete Harvester	17.5 hours	'non-picking' labour per acre
Breadth System	10.0	,,
Stint to Box system	14.0	,,
Stint to basket system	16.0	,,

The farmer may be able to obtain casual labour to perform some of the 'non-picking' tasks. The fact that a complete harvester can be worked for longer hours may make it a more attractive proposition than the high 'regular' labour figures would suggest.

3. *The Cost of Harvesting Maincrop Potatoes*

The direct cost is made up of 4 main items. These are:

(*a*) Regular labour (requirement as in above table).
(*b*) Tractor costs.
(*c*) Depreciation and running costs of special equipment.
(*d*) Picking cost.

(*b*) Tractor Costs

The number of hours tractor time required for the various systems was found to be as follows:

Complete Harvester	14.0	tractor hours per acre
Breadth System	7.5	,, ,, ,, ,,
Stint to basket system	9.0	,, ,, ,, ,,
Stint to box system	14.0	,, ,, ,, ,,

(*c*) Depreciation cost, etc

It is assumed that a farmer would have a foreloader on the farm in any case. Therefore the box system will need an extra attachment to tip the boxes, which would cost approximately £170, and a supply of 5 cwt pallet boxes costing approximately £5 each.

If the tipper is depreciated to zero over 5 years, then with interest on capital at 6% the cost per acre would be as shown in Table III.

TABLE II

System & Team	Work Rates (12-15 ton crop)		Notes
	Acres per Hour	Acres per Day	
Complete Harvester* (Single row) 4 pickers + 4 others	0.23	2.0	Worked for 9 hours
Breadth System with 6 male pickers and 4 other workers	0.40	2.4	Work for 6 hours
Stint to basket system with 12 pickers and 6 others	0.36	2.2	Work for 6 hours
Box Systems:			
7 pickers (+2 others)	0.18	1.1	Pickers work for 6 hours. Regular men work longer hours
10 pickers (+3 others)	0.27	1.6	
13 pickers (+4 others)	0.35	2.1	
18 pickers (+5 others)	0.48	2.9	

*Note. At the 8th International Potato Harvester Demonstration in 1963 no single-row harvester achieved a work rate above 0.29 acres per hour and so the observed average figures of 0.23 acres per hour seemed reasonable. In 1964 at the 9th International Demonstration three single row harvesters achieved or exceeded 0.32 acres per hour. This was due mainly to improved methods of clod and stone elimination on the machines. Thus with some of the latest harvesters work rates in excess of 0.23 acres per hour can be expected.

TABLE III

Acreage per Harvester per year	10	20	30	40
Cost per acre of tipping device for 5 cwt boxes	£4 8 0	£2 4 0	£1 9 0	£1 2 0

TABLE IV

Acreage of Potatoes	10	20	30	40
Cost of Pallet Boxes per year	£2 0 0	£1 13 0	£1 7 0	£1 0 0

TABLE V

Acreage harvested by machine per year	10	20	30	40	50	60
Cost per acre if Harvester cost £1,200 new	£29 2 0	£15 6 0	£10 14 0	£8 8 0	£7 0 0	£6 2 0
Cost per acre if Harvester cost £800 new	£19 18 0	£10 14 0	£7 12 0	£6 2 0	£5 4 0	£4 12 0

The boxes can be expected to last 5 years. For a small acreage (10 acres) then at least 2 boxes per acre would be needed. With large acreages (over 40 acres) then 1 box per acre should be adequate. Hence the approximate cost per acre per year would be as shown in Table IV.

Potato harvesters cost from £530 to £3,500 but the most usual models are in the range £800—£1,200. With straight depreciation to zero over 5 years plus interest on capital at 6% and assuming that running costs would be 30/- per acre (in excess of those when using an elevator digger) then the cost per acre would be as shown in shown in Table V.

(*d*) Picking Cost

The complete harvesters need 17.5 'picker' hours per acre. The rate paid is likely to be at least 5/- per hour. Hence the cost will be in the region of £4.10.0 per acre.

The highly skilled 'Breadth' picking gangs demand high wages. Present day rates range from £14.0.0 to over £20.0.0 per acre. £18.0.0 can be taken to be a reasonable cost.

Workers on Box systems have more walking to do than those on the Stint to Basket system. The result is a slightly higher rate for the Box pickers. With a 12-15 ton crop the cost would vary from £14-16 per acre for a box system and £13-15 per acre for a Stint to Basket system.

Total Cost

It would require a very rash person to attempt to compare the costs of these different systems. The figures given below are very tentative and probably have little meaning as comparisons, however accurately they represent the actual costs to different farmers.

If regular labour is costed at 6/- per hour and tractor time at 4/- per hour then the costs are as follows:

TABLE VI

System:	*Complete Harvester costing* £1,200 (40 *acres*)	*Breadth System*	*Stint to Basket System*	*Box System* (30 *acres*)
	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Regular Labour	5 5 0 (17.5 h)	3 0 0 (10.0 h)	4 16 0 (16.0 h)	4 4 0 (14.0 h)
Tractor Cost	2 16 0 (14.0 h)	1 10 0 (7.5 h)	1 16 0 (9.0 h)	2 16 0 (14.0 h)
Depreciation of special equipment	8 8 0	—	—	2 16 0
Picking Cost	4 10 0	18 0 0	14 0 0	15 0 0
Total	20 19 0	22 10 0	20 12 0	24 16 0

Most farmers would not worry overmuch about the 'fixed' costs attributed to regular labour and tractors. A second way of using the above figures is to get the difference between the other costs when deciding upon the economics of buying a harvester. The total variable costs (i.e. excluding harvester costs) are approximately £4.10.0 when using a complete harvester.

From this figure the following table can be constructed:

TABLE VII

Acreage of potatoes at which use of harvester becomes economic

Cost of Harvester	£800	£1,000	£1,200
Piecework Picking Cost of £14 per acre	23 acres	29 acres	35 acres
Piecework Picking cost of £18 per acre	15.5 acres	19.5 acres	23 acres
Piecework Picking cost of £22 per acre	11.5 acres	14.5 acres	17.5 acres

4. *Damage to the Potatoes*

This may well be the most important consideration in the future. The difference in picking cost between various systems is so little when compared with the premium available for damage-free samples that it should be the overriding consideration. With hand picking any system can be organized and supervised so as to give minimum damage but this may increase the cost. With harvesters the elimination of damage should be the first consideration of the designers.

Conclusions on Maincrop Potato Harvesting

Using the data available it seems that harvesters (depending on initial cost) are an economic consideration above a certain minimum acreage of potatoes. The greater speed of working possible due to modifications to harvesters in the past year will make harvesters more attractive to the growers of larger acreages.

EARLY POTATO HARVESTING

Production studies were carried out in June and July 1964 to obtain some basic information on this subject. It is generally considered that the handling of tubers in bulk —in pallet boxes or trailer loads—is not suitable for tender early potatoes.

Three systems were observed:

1. Traditional 'Lincolnshire' method of hand riddling in the field.
2. Various methods of carting the potatoes in small boxes (½ cwt or bushel-boxes) to a riddle at the barn.
3. Bagging off from a complete harvester.

1. *Hand riddling*

Table VIII gives the details of the overall performances and the breakdown into the different operations.

From these figures one or two interesting points arise. By having the haulm chopped off—instead of using pitchforks to move it aside—some 10 man hours per acre

TABLE VIII

Farm No.	1	2a*	2b*	3	4	5
Yield (Ware) Tons/acre	11.0	15.75	15.75	12.6	8.5	8.5
Worker Hours/acre	74.2	84.3	65.9	75.25	79.0	56.3
Worker Hours/ton	6.74	5.35	4.18	5.95	9.3	6.6
Percentages						
Picking	43.7	41.4	54.0	38.0	53.8	50.8
Walking to Riddle	8.7	10.1	11.3	10.4	8.7	11.1
Riddling, weighing and sealing bags	20.6	32.8	17.9	29.1	23.0	22.5
Tractor Time (Spinning and harrowing)	6.0	11.5	11.5	10.8	9.5	10.6
Loading	3.3	4.2	5.3	3.9	1.7	3.6
Forking Haulm	14.5	—	—	—	—	—
Miscellaneous (waiting etc.)	3.2	—	—	7.8	3.3	1.4

*The observed figures for farm No 2 were 70.5 worker hours per acre and 4.48 worker hours per ton. This was when ¾ of the crop went in 1 cwt sacks and the remainder in ½ cwt paper bags. Column 2a is an estimate of the performance when using ½ cwt bags and Column 2b an estimate of the performance when using 1 cwt sacks.

can be saved. A two-row tractor-mounted haulm pulveriser was observed to work at a rate of 45 min/acre. This was used on two farms. Two others had a simple 'haulm chopper' fitted to the front of the tractor on which the spinner was mounted.

On farm No. 2 the riddling, weighing, sealing and stacking aside of 1 cwt of potatoes took 3½ min longer, on average, when ½ cwt paper bags were used than when 1 cwt sacks were used. The extra time necessary for straightforward sealing and stacking with paper bags amounted to only 0.80 min. The other increase indicates the prevalence of over-filled bags, split bags, bags slipping off the holder and the workers' general dislike of using them.

These figures also show the possible savings that could be expected from mechanization. For instance if the loading were mechanized the saving could only amount to 2-3% or up to 2½ man hours per acre. If the walking were halved by having the riddles on movable stands the saving could be approximately 5% or perhaps 4 man hours per acre. The average stint length was 42 yards for the five farms. The effect of excessively long stints on output (i.e. with very long fields) can be estimated if it is assumed that the walking distance would be more than doubled with doubling the stint length.

It is interesting to see how the work rate might vary as the crop matured. A typical result for a 10-ton crop might be:

Man hours per acre . . 70

Comprised as follows:

Picking	41%
Walking to riddle	10%
Riddling, weighing and sealing bags . .	27%
Tractor work (spinning and harrowing)	10%
Loading	4%
Miscellaneous (waiting etc.)	8%

The time spent walking, riddling and loading will be directly proportional to yield. The time spent on tractor work and miscellaneous items will be constant irrespective of yield. The time spent picking will be almost constant. The difference between picking a 5-ton crop and a 10-ton crop need only be the difference between picking up a number of 2 in potatoes and the same number of 2½ in potatoes.

If (for want of better information) it is assumed that a 50% change in yield would result in a 10% change in picking time then the labour requirements might be as follows:

5-ton crop	53 hours per acre	10.6 hours per ton
10- ,, ,,	70 ,, ,, ,,	7.0 ,, ,, ,,
15- ,, ,,	87 ,, ,, ,,	5.8 ,, ,, ,,

Having arrived at these figures they can be usefully employed in assessing the economics of various methods of mechanizing all or part of the harvesting.

2. *Riddle at barn*

Thanks to the wholehearted co-operation of one farmer it was possible to observe the same gang of pickers working three different systems. This gang of eight male pickers was supplied by a local 'gangmaster' and they were paid on a piecework basis. Their rate of work was probably at least 10% higher than the average of the workers observed on the hand riddling systems. The three methods used were as follows:

(a) Stint Method

This was the normal method on the farm. The haulm was chopped off. A two-row elevator digger was used. Bushel boxes were placed down the field and the pickers tipped their baskets into them. Each picker had an allocated stint approximately 28 yards long. Besides the 8 pickers, one man worked full time on the elevator digger and the harrows, four men were 'teaming' and six were at the barn. The teamers loaded the full boxes onto trailers. They had three tractors and trailers, one of which was left at the barn. At the riddle (a converted tulip riddle) one man tipped the boxes on, one man sorted the damaged tubers and the other four worked in two pairs, bagging off, weighing and stacking on pallets.

(*b*) Pallet Method

In this system four double rows were lifted for the whole length of the field. Four pickers started at each end and all eight men worked towards the middle. Down the side of the bout pallets were placed at 13-yard intervals. Each pallet had one layer of seven empty bushel boxes. The pickers tipped their baskets into these boxes. Four pallets were loaded onto each trailer by a foreloader. The 'teaming' gang consisted of three men, one with the foreloader and two with three tractors and trailers. The team at the riddle was unaltered.

(*c*) Breadth Method

Eight double rows were dug out and the pickers started at one end of the field working down them. The baskets were taken to a trailer backing down behind the pickers. On this were approximately 60 bushel boxes. A row of empty boxes was placed across the back of the tractor.

When these were filled they were replaced and stacked at the front of the trailer. The 'teaming' gang was two tractor drivers using three tractors and trailers and two workers stacking the boxes on the trailer. The team at the riddle was unaltered.

The table below gives the details of overall performances for the three systems.

TABLE IX

System	*Yield and Variety*	*Time system observed*	*Man hours per acre*	*Man hours per ton*	*Picker Hours per acre*
Stint	Ulster	384 min	60	6.0	25
Pallet	Prince	240 „	61	6.1	26.4
Breadth	10 tons	334 „	54	5.4	22

After allowing for the higher rate of work of the pickers it is doubtful if any savings are made over hand riddling except for the 'Breadth' method. The elimination of the manhandling of the boxes in the field by using pallets resulted in very slightly lower non-picking hours but in higher 'picker' hours per acre. The lower 'picker' hours figure on the 'Breadth' method was caused partly by the fact that one of the slowest pickers was working next to the trailer and only spent 10.8% of his time not picking. This compared with a range of from 13.5% to 21.4% for the eight men when on the stint system. There was some indication that the time to fill each basket was reduced on the 'Breadth' system. This may be due to some psychological factor of the men working together as a team.

3. *Use of Complete Harvester*

A brief survey of harvesters used for early potatoes enabled three models to be observed and information collected about a fourth one. The harvesters were organized as follows:

(*a*) Grimme Harvester

The team consisted of four men. One was on the towing tractor; one man was bagging off, weighing and sealing and two men were on the sorting table. The potatoes were packed in ½ cwt paper bags. The full bags were stacked on the platform and transferred to a trailer at the end of each 'round'. Up to 15 cwt could be stacked on the platform. The tops were not cut off in any way. The soil was light and almost free of stones.

(*b*) Whitsed Harvester

The team consisted of five, comprising three men and two women. One man drove the towing tractor. One man and two women were sorting and one man was bagging off, weighing and sealing. 1 cwt sacks were in use when observed but ½ cwt paper bags were also used. Up to 11 cwts were carried on the platform. The sacks were unloaded at the end of each row.

The tops were chopped by a cutter on the front of the harvester. The soil was quite sticky in places. The main problem was the number of chats which were not eliminated by the riddling arrangements on the machine.

(*c*) Johnson Minor Harvester

The team consisted of seven workers. One man drove the towing tractor, four women were picking the potatoes off, one man was changing bags and weighing and one man was fastening the bags and stacking them.

On this harvester all the potatoes have to be picked off by hand.

The platform could only hold about 12 bags (6 cwt) and so stops were made every 100 yards or so to unload the potatoes.

The tops were not cut off. The soil was moist but not sticky.

(*d*) Ferguson Harvester

It was not possible to see this machine in action.

The team consisted of six workers. One man drove the towing tractor, four women were picking the potatoes off and one man was weighing, sealing and stacking the ½ cwt bags. Up to nine cwts were carried on the platform.

On this machine all the potatoes have to be picked off by hand.

The performances observed were as in Table X.

From these figures it appears that saving labour of the order of six worker hours per ton with a five ton crop down to two worker hours per ton with a 15 ton crop can result by using a complete harvester. This saving of 30 hours per acre (as compared with hand riddling) must be set against: (a) the cost of running the harvester and (b) the value of the potatoes missed by the harvester.

The 30 hours saving is probably worth between £8 and £10. From the figures published by The Potato Marketing Board from their Harvester Demonstration of 1964 it would appear that the 'leavings' of ware potatoes can be as little as 0.8 or as much as 25.0 cwt per acre. These potatoes would be worth at least £1 per cwt early in the season.

The most common harvesters in use cost from £800-£1,200 and would normally be depreciated over 5 years. From the previous table it seems as though the use of a harvester is not financially worthwhile unless it can be used for a reasonable acreage, but this acreage could include late (maincrop) potatoes too.

Nevertheless many farmers will use a harvester because it eliminates their dependence on gang labour. By the removal of stooping the farmer will probably find it easier to get 'pickers'—at lower wage rates—and prepared to work longer hours.

Comments on the Harvesters Observed

Apart from the Grimme harvester the working and stacking platforms were very restricted in area. The elimination of chats was not too effective and some arrangement of a riddle—which could be changed as required—would be an advantage.

TABLE X

Harvester	*Yield Ton/acre*	*Variety*	*Observed Worker h/ton, including loading*	*Notes*
Grimme	5.5	—	3.65	
Whitsed	10.5	Red Craig Royal	3.58	In 1 cwt sacks.
Johnson Minor	12.0	Red Craig and Ulster Prince	} 3.75	Pickers not so busy when on Prince
Ferguson	—	—	—	Not observed. Farmer reports 3.25 hours as 'Good' performance. Average probably higher than this.

TABLE XI

Viner or Viners on Farm	*Acreage of Peas*	*Farm Acreage (arable)*	*Minimum labour force required for vining excluding transport to factory*
2 mobiles	350—400	1,500 upwards	(2 shifts of 6+mechanic) 13
1 mobile	160—200	1,000—1,400	(2 shifts of 4+mechanic) 9
1 static	75— 90	350—800	(1 shift by existing methods) 6-11

On the Grimme and Whitsed the sorters worked by 'subtracting' clods from the potatoes and potatoes from the clods. On the Johnson Minor and Ferguson the pickers had to 'select' every potato and place it on the correct belt. It appears that by using the second method it may be possible to keep working under soil conditions when otherwise riddling at the barn would have to be undertaken. Thus the ability to change a harvester from a 'subtraction' to a 'selection' method is a useful attribute.

Some form of inspection after the riddle and just before the bagging point may be needed and room for this should be provided.

An 'emergency hopper' holding up to 2 cwt of potatoes and fitted near the bagging point would be very useful. Whenever there was a hold up with the weighing or changing bags the potatoes could be diverted into the hopper to save stopping the whole machine.

Conclusions on Early Potato Harvesting

Hand riddling methods take from 53-87 man hours per acre. Carrying potatoes to a riddle at the barn will improve quality control but may not result in the saving of labour unless a 'Breadth' system is used.

Complete harvesters can be expected to save approximately 30 worker hours per acre (compared with hand riddling). Against this has to be set the cost of running the harvester and the value of the extra potatoes missed (if any).

HARVESTING VINING PEAS

The increased mechanization of this operation is bound to be one of the most interesting aspects of arable farming in the next few years. During the 1964 season (following the modifications since 1963) mobile viners gave satisfactory results for the first time. If the processing firms insist that these very expensive machines are used for 24 hours per day, then the resultant distribution of viners on farms and labour required is likely to be as shown in Table XI.

The ultimate result, as the static viners wear out, may be that mobile viners will only be available to farmers or groups of farmers with over 1,000 acres. During the next 10-15 years the size of farm likely to have a static viner will probably not have sufficient regular labour to man it by present methods. Thus, pea vining will be the highest labour peak on these farms. Any saving of labour in vining will be worthwhile—almost irrespective of cost—if it results in a reduction of the permanent farm labour force.

In order to obtain some information on this subject a brief survey of pea vining organization was carried out in July, 1964. The team for a static viner varied from 6—11 persons. Many farmers had developed labour-saving ideas to eliminate some of the jobs at the viner. From these observations and following discussions with various interested parties the following suggestions for reducing the size of the vining team are put forward.

(*i*) *The Problem*

The whole series of problems—apart from the cutting of the haulm—consists of exercises in methods of materials handling. In 1963, trials at the Pea Growing Research Organization gave the following results:

	Wt. of Haulm per acre	*Ratio of weight of haulm to vined peas*
Average of eight quick maturing (early) varieties	6½ tons	3.5:1
Average of five intermediate (mid season) varieties	10 tons	3.8:1
Average of seven slow maturing (late) varieties	14 tons	4.4:1

All were cut at a tenderometer reading of 120. In practice lower yields could be expected. It is the bulk of haulm that the viner can take that is the ultimate limiting factor and not the weight of vined peas. Four tons of haulm per hour seems to be a reasonable feeding rate for static viners.

(*ii*) *Cutting*

The actual rate of cutting varies greatly. An 8 ft cut machine can easily keep two viners going and on some farms the cutter driver also drives the loader. With laid crops one-way cutting is often practised and this increases the time needed by up to 50%. The main worry is breakdowns. Whenever possible a second cutter should be available and of course a spare belt and two spare cutter bars. When the cutting is slow then 2-3 hours work is usually done in the evening to get ahead of the viner.

(*iii*) *Loading*

With a static viner at the farm then the problem is that of getting up to four tons of haulm to the viner each hour. On farms where the cutter drivers also drive the power loader they fill four-wheeled trailers. These could be expected to hold up to 2 tons. With a 'Hume' loader the loading of a large trailer would probably take the driver away from the cutter for 10 min. The loading of a small (1 ton) trailer would probably take the driver away for 8 min. Thus, when loading 4 tons per hour the cutter could work for 40 min with large trailers but only for 28 min when loading small trailers.

The whole concept of using a loader requiring a special tractor and driver must be regarded as a retrograde step—to be avoided unless the cutter driver can drive it. This will only be possible if large trailers are used. A green crop loader with an automatic drawbar extension hitch (such as the 'Wilder Steed') can be used to load small trailers. This would not need any other person present apart from the tractor driver.

(*iv*) *Transport to the Viner*

This is the operation which will be the most variable in labour usage. If a large (2 ton) trailer can be loaded mechanically in 10 min and a small (1 ton) trailer loaded by a green crop loader in 8 min, then with field travel of 220 yards at 4 mile/h, road travel at 10 mile/h and allowing 2 min to change over at the viner: the maximum distances over which the various transport teams can work (carting 4 tons per hour) are as follows:

TABLE XII

Trailer Size *ton*	*System*	*Maximum Transport Distance (each way) including field travel yards*
1	1 man with one tractor and trailer tipping at viner or 1 man with two tractors and trailers leaving one at viner	400
1	2 men with two tractors and trailers tipping at viner or 2 men with three tractors and trailers leaving one at viner	2,600
2	1 man with two tractors and trailers leaving one at viner	2,300
2	2 men with three tractors and trailers leaving one at viner	6,650

If some peas must be grown a long way from the viner then the situation can be eased by growing early varieties on the distant land as the bulk of haulm is less with these. The siting of the viner should be in the middle of the 'best' or 'late' land.

Any system involving consolidation of the load must be avoided as it requires one extra man in the field and slows down the work at the viner. It is probable that 4-wheel drive tipping lorries with high cage sides are the best transport for haulm from a distance.

The use of self-unloading trailers may be a possible future development. (See under 'Feeding the viner').

(*v*) *Feeding the viner*

Feeding by a tractor-mounted 'grab' with a device on the viner to even out the flow of haulm is possible. Most farmers who have tried it consider that this device did not work satisfactorily.

It seems probable that hand feeding will continue on many farms. Two men will be required and it would be unwise (for safety reasons) to reduce the permanent team at the viner to less than two men. Thus, with the elimination of all other jobs these two will still be able to feed the viner by hand.

With self-unloading trailers—geared to empty at a rate of 4 tons per hour and with a suitable hopper on the viner then one man could attend to the feeding.

(vi) Disposal of Waste Haulm

On many viners waste drops down at odd places. Home-made conveyors have been constructed on some to take it to the main conveyor. It is essential that all waste should be conveyed mechanically to one point. A farm elevator would then be used to accumulate it at a point some 10-15 yards from the viner.

No labour should be used during the day to attend to this waste. If it is to be collected by another farmer it can stay in a heap until called for. Dr A. Eden of the Nutrition Chemistry Department, (N.A.A.S., Cambridge) considers that waste haulm left in a heap for up to three days will make perfect silage if it is then stacked. If the silage is required on the farm then suitable sites for pit or clamp silos would radiate from the 'waste accumulation point'. The clamp work need only be carried out twice per week. A large tractor with a scraper blade might be used. An alternative solution is to have a circular 'weldmesh' silo below the end of the elevator. With a spinning plate or other type of distributor on the elevator, the silo could be filled without any hand work apart from finishing off the top.

If the waste is to be composted it might be allowed to accumulate for a week before being bulldozed aside into a heap. It is probably economical to use hand labour to stack the waste haulm.

(vii) Handling of the Vined Peas

On some viners the peas fall into trays along the whole length of the side. A conveyor to take these to one end is essential. At the end a second conveyor/elevator should take the peas up into a raised hopper.

With processors who use bulk (12 cwt) containers the hopper need only be small and would be used whilst the bulk container below it was changed. Equipment needed will include a hand pallet truck and a fork-lift attachment on the rear of a tractor. The labour required should not exceed two minutes for changing containers every 35-40 minutes and 10 minutes loading the lorry every two hours.

If some processors insist on using small trays the raised hopper will need to be much larger. It should hold all the peas that are vined during the time that no lorry is present at the viner. This may not be practicable in some cases and so some trays would have to be filled and stacked. Below the hopper the trays would pass along a roller conveyor which would be slightly higher than the floor of the lorry. To avoid double handling the trays would be taken from the lorry, filled and then returned to the lorry via the roller conveyor. In this way the handling of the peas should only take up 60 minutes in each two hours. This operation should be within the capabilities of a female worker.

(viii) Transport of Peas to Factory

No mention of the organization of this job will be made here. Although many farmers' lorries are now used, it is doubtful if this will be possible in the future with less farm labour available. Contractors' lorries are normally available. The number of lorries needed will depend on distance from factory and on the processors' regulations.

Conclusions on Pea Vining

It will be possible to manage a static viner with teams of four or five men (depending on distance to crop) if the peas go away in bulk containers.

If small trays are used then an extra worker (man or woman) will be needed in each case unless self-unloading trailers prove to be satisfactory, thus releasing one man from feeding the viner.

Possible methods of organization are as follows:

(a) Four-man team

One man on cutter also driving power loader to load large trailers; one man with two tractors and trailers, leaving one at viner; two men at viner *or* one man on cutter; one man with two tractors and smaller trailers loading by green crop loader with extended hitch at rear of trailer; two men at viner.

(b) Five-man team

One man driving one cutter and also driving power loader to load large trailers; two men with three tractors and trailers; two men at viner *or* one man on cutter; two men with three tractors and smaller trailers leading by green crop loader with extended hitch at rear of trailer; two men at viner.

Although saving labour is likely to require fairly heavy capital expenditure it will probably be worthwhile if the result is the reduction of the permanent farm labour force.

GENERAL CONCLUSIONS

In order to assess the true economic advantages of some aspects of agricultural mechanization the use of work study techniques appears to be most useful. One of the most important aspects of Work Study in the N.A.A.S. should be to observe and examine new developments (and if possible to help with the developing of them), and to influence the thinking of advisors with regard to these new techniques.

By finding out the work rates available with new machinery and by observing those obtained by existing methods, Work Study Officers can provide evidence of the economic implications of further mechanization. Accurate data on labour requirements should pinpoint the tasks which offer the greatest scope for future mechanization.

DISCUSSION

Mr H. G. Pryor (Farmer) sought clarification of some of the figures in Table II of the paper with regard to stint-to-basket performance and box system performances. He added that if the figures for complete harvesters had been taken from the National Trials he felt they were of little value from the statistical angle. Mr Edwards replied that the compilation of these figures had been generally based on what he would describe as production studies but he could not say on exactly which studies Mr Hall had based his figures as there had been many studies carried on in recent years. They did not strike one as being out of the ordinary compared with the studies he had been engaged on. The basic method of collecting these figures was for a team of three or four officers firstly to familiarize themselves with the system on the farm and then to break down the tasks and take a production study or timed check on the various operations performed. At that stage no attempt was made to study whether these were good or bad methods. The figures were collated and broken down, usually to include all the items of picking, of waiting about and of transport. The figures were then produced in the form of acres per hour or man hours per acre. Mr Edwards said he could not state on what basis the complete harvester figures were compiled, but they did not seem to him to be out of place for single-row harvester. The speed of these machines indicated that one could not expect a working rate of more than ¼ acre per hour. He thought that the bigger machines taking more rows would probably cover increased acreages, but while the single-row machine remained he could not see anyone with a large acreage taking much interest in it.

Mr J. B. Holt (National Institute of Agricultural Engineering) raised a point about the manner of working of breadth system pickers. He had noticed that it seemed quite common for breadth pickers to work flat out for a period of about twenty minutes and then have a break of about five or ten minutes, possibly according to the weather. Mr Holt asked whether from the work study point of view this was the best way of setting about this kind of work, bearing in mind that it was a rather uncomfortable working position; it might be better if the pickers worked more slowly but for a longer period. Mr Edwards felt this lay entirely within the field of ergonomics, but some thought had nevertheless been given to the study of human behaviour. Generally speaking most workers would appear to work hard for a short period and then have a short break. During the previous year on one of the N.A.A.S. Experimental Husbandry farms an attempt had been made to assess the two systems comparatively, using the same figures, the same field and the same machinery. He and his colleagues had been rather unfortunate in that they found on arrival that the picking team consisted of a gang of women each with children ranging from about 3 to 14 (who should have been at school). One of the work study officers on the breadth system was kept very busy shepherding children away from the wheels of the trailer, so that he could not say it was a successful breadth system. However, he had asked all the women individually their opinion on this. They liked the breadth system and were all happier on this basis of working than on the standard stint system, where the rest period depended firstly on the speed with which they picked their own stint and secondly on whether the diggers were coming round fast enough to catch them up. The normal type of picker associated with breadth labour—sometimes termed Irish labour—was generally out for one thing only, namely money. His whole aim was to work as hard as he could for as long as he could and Mr Edwards said he had been astonished at the rate which these men could sustain for a long period. The answer to the question, however, was that generally a short spell of hard work followed by a break appeared to be more satisfactory to the picker than a steady working period at not such a heavy rate, when there were delays caused by other factors than the picker's own desire to have a rest.

Mr J. M. Chambers (New Idea Farm Equipment Ltd) remarked that the paper covered the harvesting of only two crops, potatoes and peas. He would like to ask Mr Edwards if work studies were being carried out by the N.A.A.S. or other people on other aspects of farming such as work with reversible ploughs—possibly square ploughing or round the field ploughing. Mr Edwards said a lot of work had already been done on the factors of round-and-round ploughing as against up-and-down working. He believed the N.I.A.E. at Silsoe had prepared some material on this already; a lot of information was available on those factors. Milking machinery had been work studied to almost the last extreme; there was a wealth of information on milking routines and milking machinery.

Mr Edwards then went on to describe the way in which the Advisory Service approached work study problems. There were a limited number of full-time work study officers drawn from various disciplines such as general agriculture, horticulture and machinery, and some of the personnel in the Agricultural Land Service had been specially trained. Officers were scattered through the country and certain projects were undertaken by groups. Potatoes had been taken as a group project over the previous three or four years. In addition each officer according to his own bent or desires would undertake local studies, suggested by other officers within the N.A.A.S., which would ultimately be of benefit to Advisers. Examples in horticultural practice were packing systems, packing routines, the handling of packing equipment and packed boxes, not always with a view to mechanization. There were considerations at present that might lead to the study of such items as the handling of irrigation pipes in the field, which consumed a lot of labour and was a job generally not liked by the worker. He himself had spent some time studying pig routines, tulip bulbs, daffodils, chrysanthemums, water cress and other products. Mr Edwards suggested that work study techniques themselves were of general application and there was no job in which they could not be of help in some way or another. Answering the question further, he said that intensive group studies had been done on potatoes. Individual officers had been and still were developing studies on particular items, of which Mr Hall's work on vining peas was an example.

Mr J. Chambers asked when further information would be available. Mr Edwards said that information on potatoes was generally circulated within the Advisory Service and any farmer could call for that advice. Occasional papers had been contributed to such publications as 'Agriculture'* and in the general farming press, but generally speaking until N.A.A.S. were completely convinced and satisfied with regard to these items they were not written up. Mr Edwards said he felt work study was still a relatively new baby. Really intensive interest in the agricultural field began about 1956, which was not a very long time ago.

It was necessary to be sure of all the facts before they were published. The information in the tables in the paper had been gathered by a team and the detail was not always generally applicable. He would suggest that there was no best overall method of doing any particular job. One could publish the generalities of systems, of which several were to be found in the Paper, but the detail of any system would depend almost entirely on the individual circumstances of the particular holding where the work was done. He hoped that eventually there would be more publications on the work that had been done. Ministry of Agriculture publications covered some fields; in machine milking, for example, there were Ministry bulletins in which a great amount of detail concerning milking systems and performances was cited. Mr Edwards added that whilst he did not believe that any other full work study reports were to be found within the N.A.A.S. he sincerely hoped these would be forthcoming within the next year or two.

Mr R. A. Jossaume (Cleales Ltd.) asked whether it was too early yet in the field of work study to be able to draw any comparisons in rates of work as between the Fenland farmer and the Upland farmer respectively. Mr Edwards replied that it was important to bear in mind the difference in conditions. Although the same amount of work went into any given job no matter when it was done, the conditions surrounding it varied greatly over the whole country. The different performance rates of workers were really social factors, in that one found that a worker and a farmer would be attuned to the type of area in which they lived. Mr Edwards said that a number of his colleagues who had moved from one district to another, not necessarily from Fenland to Upland, had noted that the pace of farming, and indeed of life in general, had dropped as much as 50% below what they had previously experienced. If this was true of life in general it followed that the rate of work would alter accordingly. An intensive highly mechanized high-input farm of the kind one often found on the Fen would attract high quality labour because they could earn a lot more money. In the Upland areas, however, where there was less arable farming, there was perhaps a relatively slower way of life in general. Mr Edwards said he would hesitate to say that the Fenland worker worked at a rate of 50% faster than an Upland worker; although it might be true of some jobs, in others the opposite might be the case. Certainly the general pace of work varied between different areas and for this reason when conducting work study on say potatoes, investigations were carried out in potato growing areas such as around Boston and in the Vale of York. Data had been compiled from results based on comparable conditions.

Mr R. M. Chambers enquired of the speaker how he approached the workers when work study was to be undertaken. Presumably work study was directed at reducing the amount of work put into any job and it would be interesting to know whether any of this was taken into account in the approach to the workers or whether one went into the field and just carried on without telling them what was being done. Mr Edwards said he was glad of the opportunity to answer this point because he knew of farmers who carried a stop watch around with them in their pocket and took care not to show it. It was a habit he deplored and whatever type of study he was engaged on he believed the workers must be fully informed of what was happening. The ideal type of job in his experience was when the workers themselves asked the employer to bring somebody in to advise on reducing the work. He refused to work under conditions of secrecy. If a worker knew he was being studied he would have a different reaction, he might work faster or slower or he might work awkwardly or too co-operatively, but generally speaking he had found that provided the workers knew what was happening and why, then they were happy to co-operate and would often good humouredly tease the officer who was trying to do the job. Mr R. M. Chambers rejoined that this was a different state of affairs from that of the factory worker when the rate-fixer was in the vicinity. To this Mr Edwards replied that he had been concerned with certain industrial organizations. He believed the reaction of a worker to what was termed 'rate-fixer' was purely a question of the worker-management realationship. He believed that agriculture was peculiar in the respect that there had rarely, if ever, been any real rouble between what one might colloquially term 'man and his master'. He did not believe one would ever encounter that kind of effect in agriculture. One might find the man who deliberately slowed down or one who would work twice as fast in an attempt to be awkward, but with rare exceptions he had never found any trouble at all and this was entirely due to there being a good working relationship between the employer and the worker.

Mr G. C. Mouat (Essex Institute of Agriculture) wondered whether, in view of the good results from the breadth system of picking, this meant that one would see an increase in the use of this system outside the areas where it was traditionally used. He would like to know whether there were problems in persuading people to adopt a system like this when they had been used to some other system. Secondly, if the breadth system were more widely employed, was there likely to be a corresponding decrease in the use of the box pallet system in handling potatoes, or alternatively, what were the advantages of the pallet system of handling that would tend to perpetuate

* The monthly Journal of the Ministry of Agriculture, Fisheries and Food.

the existing system? Mr Edwards replied that a problem in changing to the breadth system was one frequently encountered in agriculture. Workers did not like changing, although as a result of the gospel of the breadth system having been preached in a number of places, there had been a number of changes. Children constituted a problem in the urbanized areas where women gangs came to pick and he felt certain that the breadth system would never work where there were small children running around the field. The second problem concerned the question of payment. Very often with stint systems and especially with boxes, each picker was paid a rate per box. With the breadth system one could only work on the basis of a rate per gang and, as in any other system, the rate of work if one applied it to individual rows would be the rate of the slowest. With a good gang who were working together or with a good gang master who would apportion the payment in a way acceptable to the gang, there was unlikely to be any trouble. The other point concerning women was the question of emptying baskets. This was a physically heavy task, even when emptying into ordinary low-sided trailers and women did not like it, although they would do it. Mr Edwards said he believed the breadth system would spread where capable labour was available. He knew of three or four cases in his own region during the past year where it had been tried as an experiment. In one instance it had been attempted in an awkwardly shaped little field because a harvester could not go into it. The farmer introduced his stint gang to breadth harvesting and was so pleased with the breadth system that he switched his gang straight from stint to breadth. He had found this generally to be the response. So far as box pallets were concerned, or for that matter the stint system, there was one respect in which the breadth system was at a disadvantage. In the breadth system the transport unit was integrally tied up with the picking gang. It moved as part of the gang and if there was no empty transport available, then the entire gang had to stop and wait. This did not generally occur with the stint or box pallet systems. The pallets were put out by the regular gang beforehand for the pickers to fill up. This was the great advantage of the stint system, but on the other hand there was a lot of work to be done before picking started and further work to be done at the end. The big advantage of box pallets was that these could be bulked up into reasonable unit loads a little earlier in the operation and broadly speaking the sooner one could get anything into a unit large enough to handle as a unit load, the better the system would be.

MR J. H. W. WILDER (John Wilder & Co. Ltd.) asked about the relative merits of either pulverizing haulm or leaving the haulm. Mr Edwards said he could not quote any figures at presen tother than those shown in the Paper, but generally speaking both with the main crop and with early potatoes, there was no doubt that pulverizing the haulm would increase the rate of picking whether by the breadth or the stint system. Eliminating the onerous job of shaking haulm away and of digging into piles of haulm to find the potato could effect a big saving to the picking gang. Mr Edwards drew attention to Table VIII in the Paper and to the text immediately following it.

MR F. S. MITCHELL (National Institute of Agricultural Engineering) asked if Mr Edwards could describe just how he had obtained the figures for those studies and whether, when he was carrying out his measurements in the field, these covered a large group of elements or whether they had been taken in fairly fine detail. He also asked whether direct comparisons had been made between the breadth method of picking and the stint method when all other things were equal, because it might seem from the discussions going on that one of the great virtues of the breadth system was that one obtained a continuous supply of potatoes. This meant that a considerable amount of work had to go on beforehand to get all the potatoes lifted and weather difficulties might be encountered. Mr Mitchell asked whether the same result could not be obtained from the stint system also, by giving the pickers a continuous supply of potatoes. They would have to work across the field, but this would allow the pallet box system to be employed more readily. Mr Edwards said that the questioner had touched on one of the standard difficulties of putting theory into practice. So far as elemental details were concerned, work had been conducted on picking baskets of known average weight. In one particular study there had been an attempt to determine the average weight of baskets, the number of tubers per basket, the rate of picking per basket, the rate of walking and the speed of emptying on the breadth system. He had personally worked on a similar sort of programme on stint systems so that a reasonable amount of detail had been obtained, but unfortunately there was insufficient material for publication at the moment. Mr Edwards said that one of the difficulties was in defining the conditions under which one was working so that these figures could be used in other cases. There had been a sufficient break down of detail to show that in three or four stint systems the pickers could spend anything up to half their time waiting for potatoes to pick. The big saving on the breadth system was a reduction in this waiting time. Another reduction that one could effect was by lifting potatoes ahead of the stints, provided that a type of digger was used that would lift potatoes adjacent to those that had just been lifted. When this occurred it was possible to get some very good performances on stint systems. Mr Edwards said that his recollection was that in the ordinary system of stint picking where boxes were spaced 12 yards apart and the boxes were moved up about every 10 or 12 rows, it entailed walking distances of more than three miles per acre backward and forward to empty potatoes into the box. In addition, to maintain the position even at that level meant employing someone with a tractor and a lift to keep the box close up to the pickers. Given a well-knit breadth system on the other hand, pickers would rarely walk across about more than 4 or 5 rows of potatoes. Mr Edwards said that he would very much like to have an answer to the problem of leaving lifted potatoes exposed to the weather. Farmers who adopted the breadth system were perfectly prepared to risk a few potatoes being out. There was no need to be many acres ahead of the gang; it was only necessary for the lifting machinery to be one breadth ahead. The best system he had seen was one in which the lifter operator, using a two-row potato plough, spent about half an hour in the morning lifting the morning's picking and then went off for two or three hours ploughing. He would return at lunch time while the pickers were having a break, spend another twenty or thirty minutes lifting and then go off again. Those farmers who adopted the breadth system were not worried about a few potatoes being left out, they were prepared to risk them and store them separately if necessary; on the other hand those farmers who disliked the breadth system felt that potatoes must not be left out and this, said Mr Edwards, was the extent of the information he had on this point.

APPOINTMENTS SERVICE

Members are cordially reminded that a monthly list of situations vacant in the agricultural engineering industry, teaching and research, both in Great Britain and overseas, will be supplied on request.

Those wishing to avail themselves of this service should notify the Institution Secretary. It would be appreciated if members would inform the Institution of changes of appointment, in order that office records may be kept up to date and, where applicable, the circulation of lists from the Appointments Service terminated.

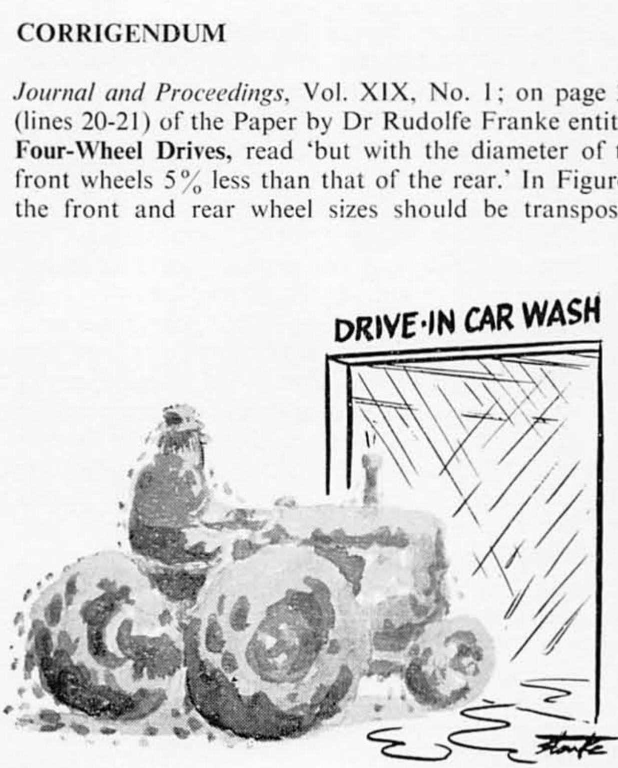
INSTITUTION TIE

As announced in previous issues of the *Journal*, Institution ties are available, incorporating the design of the Presidential Badge on either dark-blue, dark-green or dark-red grounds. These attractive emblems may be purchased and worn by members only ; they are available in any quantity at a cost of 15/- each, which charge includes packing and postage.

Order forms may be obtained from the Institution Secretary.

CORRIGENDUM

Journal and Proceedings, Vol. XIX, No. 1; on page 26, (lines 20-21) of the Paper by Dr Rudolfe Franke entitled **Four-Wheel Drives,** read 'but with the diameter of the front wheels 5% less than that of the rear.' In Figure 4 the front and rear wheel sizes should be transposed.



(Reproduced by permission of "Punch")

THE SUSCEPTIBILITY OF FRUIT AND POTATOES TO DAMAGE DURING HANDLING

by H. C. GREEN*

Presented at an Open Meeting of the Institution in London on 28 January 1965

Introduction

Damage to agricultural and horticultural products is serious, affecting both the producer and consumer in that it represents a loss—a loss more serious than poor yields, since the crop is grown, harvested and handled at great expense and is then unsaleable. Even worse, the damaged product may be a source of infection to the sound product with which it is in contact, and even an elaborate store is not proof against the danger of the damaged and infected apple. Damage will detract from the value of all products due to poor appearance. Badly skinned early potatoes and bruised apples look unattractive, but it is mainly with stored products that damage is of greatest importance, or if there is a delay in marketing with a soft fruit like strawberries. In this paper it is proposed to consider potatoes and apples in the main, as apart from grain, they are crops that are produced in large quantities in this country. They are relatively very susceptible to damage, are often stored for long periods, and mechanical handling methods for them have been rather more fully developed than for other agricultural and horticultural products.

Damage can occur at many stages in the life of the crop. Even before lifting the crop in the case of potatoes or before picking with fruit, loss and damage can occur due to greening, blight infection, and misshapen tubers due to incorrectly formed ridges, while 5% or more of an apple crop may lie damaged on the ground before the pickers enter the orchard. A considerable amount of damage is done to potatoes at lifting, and this is particularly so if the digger or harvester is not correctly adjusted to suit the prevailing soil conditions. To a lesser extent potatoes can be damaged during picking by too rough treatment and in emptying the picking baskets or buckets into bins or into trailers. Apples are particularly vulnerable at this stage, and damage can be caused by the pickers in pulling the fruit from the trees, crushing them together in their hands or dropping them into their picking bags. Further damage can occur in the picking bag itself as the pickers climb down from the tree and walk to the bin or box, and rest the bottom of the bag on the sharp edge of the bin. Additional injuries are caused when the fruit hit the sides and bottom of the bin or jostle together as they flow from the picking bag.

* Harvesting and Handling Dept., National Institute of Agricultural Engineering.

The full boxes are loaded on to trailers, jolting and damaging the fruit, while potatoes are often dropped from great heights on to the floor of trailers. Then full trailers or loaded tractors are driven over rough tracks and pot-holes, further jostling and damaging the potatoes on their way to the store. After storage, during which time there have been varying amounts of loss due to rotting developing from the injuries, the fruit and potatoes are rattled over graders, packed or sometimes crammed into boxes, and finally transported to the market for sale.

Effects of movement on damage

Since potatoes can only be damaged when there is relative movement, the greater the number of movements the greater the opportunity for damage. In general the method of harvesting or handling that has the greatest number of separate potato movements has the highest damage potential. This is of course conditioned by the strength of the fruit or potatoes themselves and their susceptibility to damage, the nature of the movement, and the size of the unit quantity of product moved at a time.

Nature of damage

Mechanical damage can take many forms, and these can be classified arbitrarily into different types. For the purpose of studying the effects of mechanical handling, the following types of damage may be considered:

Potatoes	*Apples and pears*
Skinning (mainly earlies)	Bruises
Superficial abrasions	Flats (in storage)
Punctures (by projecting mechanical parts)	Punctures
Splits (by impacts)	Splits
Internal bruises	

Importance of different damage types

The relative seriousness of different damage types depends upon the length of the storage period, storage conditions, the presence of infection, and the use to which the produet is to be put. Damage in early potatoes is not as important as in maincrop since the potatoes do not have to be kept beyond a few days; in fact, skin damage may increase the appeal to the consumer as an indication of a genuine 'new' potato. Surface injuries may be important where dry-rot susceptible varieties of potato are to be stored for some months and they may detract from the appearance of a pre-pack sample but, apart from this, shallow injuries are not necessarily important as they will be peeled away before cooking. This is certainly so with some forms of processing, where the skin with the surface injuries is removed in the peeler to reveal the deeper wounds which have to be given relatively expensive treatment by hand to trim away the discoloured tissue. It is often the internal bruises that do not show on the surface that are most troublesome, since an apparently lightly-damaged sample may require a considerable amount of hand trimming after removal of the skin. Burton and Twiss (1963) found wide variation in the amount of internal discolouration in samples of ware potatoes from less than 1% to nearly 38%, and to avoid this insidious form of damage chip processors may go to some trouble to ascertain the harvesting and handling methods used for the potatoes they buy.

Resistance to Damage

Potatoes and fruit are damaged by being loaded beyond their yield point, and the study of their mechanical strength therefore makes it possible to obtain a measure of their resistance to damage. When a load is applied to a vegetable material such as a potato it displays not only its elastic properties but also its plastic properties. Thus to study the resistance of a potato to damage it is necessary not only to examine the stress/strain relationships as for a steel spring, but also to consider the effect of the time of application of the load. In order to simplify the problem by eliminating the effects of potato size, shape, and skin strength, a cylindrical core sample may be prepared, a load applied and the amount of compression measured at intervals of time. It will be found that, within limits, the amount of compression of the sample can be related to the load and the logarithm of the time of application of the load. On removal of the load there is a small instantaneous recovery due to the elastic properties of the potato, followed by a further slow recovery eventually no doubt back to the sample's original size.

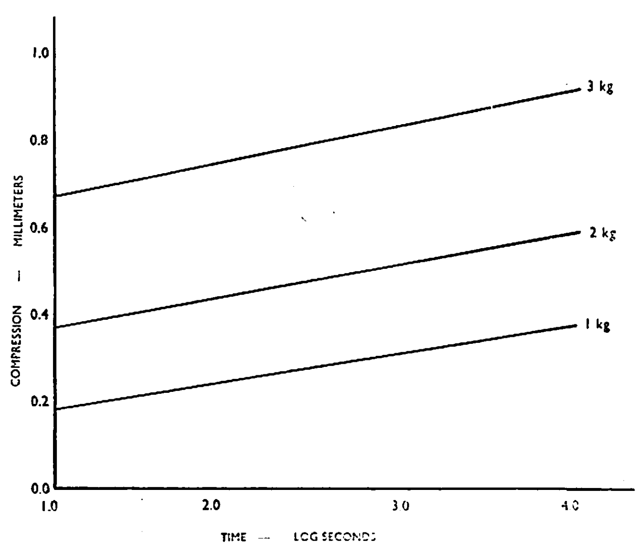


FIG. 1
Compression of 1¼ in. × 1¼ in. cylindrical core samples of potato

When an attempt is made to measure the resistance to damage of a whole apple or potato by subjecting it to a compression force, errors are introduced by the effect of the size and shape, further complicated by the different physical properties of the skin, the flesh, and in the case of apples the pips and core. The skin of a potato is tough and not capable of much deformation compared to the flesh. When a potato is compressed the flesh is deformed to a point at which the skin is stretched to such an extent that it suddenly ruptures, causing a deep split to appear. With apples the skin is particularly tough, and the cells of the flesh tend to break down locally under load with the formation of a bruise rather than a deep split except under very heavy loads. Since the extent of deformation depends upon the time of application of the load, there is a distinct difference between the effects of static loads and of sudden impacts. With impacts the potato shows its elastic properties more than its plastic ones, while with static loads it is mainly plastic; apples behave similarly but to a different degree. Different kinds of injury may therefore be expected when potatoes or apples are moving as single units than when they are being moved or stored in bulk.

Static Loads during Handling

A potato at the bottom of a bin is being subjected to a static load. The smaller the potato the less able is it to resist the load. A potato just large enough not to be rejected as a chat would just be split by a load of about 57 lb; this would be equal to something like a column of potatoes 168 feet high, assuming of course that all the load acted downwards. The corresponding figure for a safe depth for apple storage would only be about 4½ feet. Since the time factor is an important consideration, bruising can develop at the bottom of a bin after storage for some months. This is particularly often noticeable in pears which may have been very hard and resistant to damage on placing in the store, but have ripened to some extent and have become more easily injured by compression. Added to this, contact with the bottom of the bin is more damaging than is the softer fruit-to-fruit contact. The choice of optimum bin depth depends upon a compromise between maximum depth for economy of working with the minimum depth to reduce the static load, without increasing appreciably the number of bin bottoms per ton of fruit. (see Table I)

Up to now it has been assumed that the load acts vertically; this is of course not so. Much of the load is taken on the side of the container, and is generally assumed to be roughly equal to 10 lb/ft² per foot of depth, i.e. ¼ of the actual load. This side thrust results in 'bridging', so that the actual load on the bottom of a container need not be very great, and will depend on the width of the container and no doubt to some extent on the vibration and consolidation of the load during transport. Information on the side thrust and the loads on individual potatoes on bulk is hard to obtain and few attempts have so far been made to measure them, but this factor is of importance both in the design of buildings

TABLE I

PRESSURE BRUISES ON CONFERENCE PEARS

Position in bin	*Number of bruises per 100 pears*					*Number of bruised pears per 100*
	Bruise diameter—mm					
	<5	5-10	10-20	>20	*Total*	
Top	12	2	—	—	14	10
Middle (9 inches)	29	16	2	—	47	36
Bottom (18 inches)	37	43	37	12	129	69
Bushel box	27	17	6	1	51	40

TABLE II

NUMBER OF POTATOES SPLITTING ON DROPPING, OUT OF 144 TUBERS PER WEEK

Tuber weight group (g).	*Date*								*Total*
	August				*September*				
	8	15	22	29	5	12	19	26	
<30	5	4	11	12	4	4	10	4	54
30-90	14	18	13	18	23	25	28	20	159
90-150	18	21	22	27	35	38	34	30	225
Total	37	43	46	57	62	67	72	54	438
Drop (cm).									
50	0	3	2	4	9	9	8	3	38
100	6	11	8	10	12	15	21	11	94
150	11	12	15	19	19	19	15	15	125
200	20	17	21	24	22	24	28	25	181
Total	37	43	46	57	62	67	72	54	438

and containers, and in the avoidance of injury during storage.

Impact Loads

Undoubtedly the main source of injuries is impacts of various forms—either by the potato being hit by some other object, or by a fall onto some other object. An apple will be bruised by a free fall of about 2 inches, onto a wooden surface depending upon the variety and the stage of maturity of the fruit. Potatoes usually split if dropped from a height onto a solid surface, the extent of splitting depending upon the energy of impact. Large potatoes therefore tend to be much more severely damaged than small ones. This is indicated by the results obtained in an experiment on the effect of maturity on susceptibility to damage. (see Table II)

There is a considerable variability between tubers in their liability to splitting. When a number of tubers of about 100g each are dropped from say, 50 cm, only about a quarter will split, but if the same potatoes are dropped repeatedly some will split on the second drop, while others do not until the fourth drop or more. When they do eventually split, the length of split for additional drops will increase at about the same rate for all tubers. This may be due to some extent to differences in physical make-up, but the way the tuber falls will have some effect. Energy may be dissipated in bounce and so not be available for the deformation of the potato, while the presence of small surface cuts and skin defects such as common scab may provide a weakness in the skin, therefore rendering it more liable to split when the potato is deformed on impact. A slightly damaged potato is probably more susceptible to serious damage than an undamaged tuber. This may make surface damage of greater significance than has been suggested above.

TABLE III

LENGTH OF SPLIT FOR REPEATED 50 cm DROPS, 100g POTATOES

Number of drops from first causing split	*Length of split cm*
1	23
2	35
3	38
4	52
5	69
6	65

In this experiment although some potatoes split on the first drop, others were damaged only on the fifth drop.

Vibration

With vibration during transport the potatoes or fruit are subjected to a very large number of small shocks that, besides causing the fruit to pack closer and increase the static loads, may cause damage by the cumulative effect of a large number of shocks.

O'Brien working in California on the transport of peaches found shallow surface bruises after haulage distances exceeding 50 miles. It was found that the bruising occurring on a 100 mile journey could be simulated by placing fruit in containers and vibrating them for 10 minutes at a frequency of 10 cycles per second and an amplitude of 0.05 inches to give a maximum acceleration of 0.25 *g* at the bottom of the box. Although the acceleration at the top of the box increased with depth of box, the minimum damage was found in the 24 inch deep box, since the proportion of surface fruit was greater with the shallowest box.

Corresponding figures for apples and pears would presumably be different from those for peaches, as their elastic and damping properties would be different.

TABLE IV
EFFECT OF VIBRATION ON BINS OF PEACHES

Depth of bin inches	*Shock loads, g.*		*Ratio of Damage, %*
	Bottom	*Top*	
16	0.25	0.75	1.37
24	0.25	1.00	1.00
32	0.25	1.25	1.17
40	0.25	1.25	1.28
48	0.25	1.30	1.32

Recent work on transporting King Edward potatoes a distance of 8.8 miles over 'B' class roads gave the results shown in Table V.

The vehicles used consisted of a 10-ton capacity articulated lorry carrying seven 1-ton capacity pallet-based bins, a six-ton capacity self-unloading bulk-handling trailer designed specifically for potatoes, and having two pairs of close-coupled wheels, a heavily built 4-ton capacity two-wheeled trailer carrying four 1-ton pallet-based bins, and an experimental self-loading vehicle with four ½-ton capacity well-based bins. The shocks were measured with electrical accelerometers placed in contact with the bottom of the container or self-unloading trailer, in the centre of the bulk, and on the surface of the potatoes. The number of shocks exceeding 0.5 *g* and 1.0 *g* were estimated from the recordings for sample lengths of the journey.

Shocks were greatest at the surface of the load, with little difference between the bottom and the centre of the load. The greater shocks at the surface appeared to be due to the greater freedom of movement of the potatoes where they were not held down by other potatoes. It was observed that during the journeys the more severe bumps were just sufficient to rock an occasional potato.

The number of shocks recorded also appeared to depend upon the speed of the vehicle and on its suspension. The partly loaded lorry was inclined to bounce and give a considerable movement to the potatoes compared to the self-loading vehicle which travelled at about the same average speed. The slower-moving unsprung trailer gave fewer shocks per second than the lorry or the self-loading vehicle, but the prolongation of the journey subjected the potatoes to a large total number of shocks. Fewest shocks were recorded for the bulk trailer. This can perhaps be attributed to the suspension, the relative shallowness of the hopper-sided body, and the advantage of a specialized and well-developed handling system compared with an experimental system and largely general purpose transport.

TABLE V
NUMBER OF SHOCKS FOR DIFFERENT VEHICLES OVER 8.8 MILES OF 'B' CLASS ROADS

Number of shocks per second

Vehicle	*Load unit: tons*	*Average Speed mile/h*	*0.5 g shocks Position in load:*			*1.0 g shocks Position in load*		
			Bottom	*Centre*	*Surface*	*Bottom*	*Centre*	*Surface*
Articulated lorry	1	19	2.1	1.5	5.5	0.2	0.1	1.7
Self-unloading bulk trailer	6	12	0.7	1.0	1.4	0.0	0.0	0.2
Unsprung 2-wheel trailer	1	10	0.9	1.8	2.5	0.0	0.0	0.1
Self-loading vehicle	0.5	18	1.8	1.8	2.2	0.2	0.3	1.1

Number of shocks per trip

Articuated lorry	1	19	3550	2520	9260	413	84	2860
Self-unloading bulk trailer	6	12	1920	2740	3830	0	0	548
Unsprung 2-wheel trailer	1	10	2850	5700	7920	0	0	317
Self-loading vehicle	0.5	18	3100	3180	3790	348	522	1910

Twiss (1963) found less damage with bulk vehicles of this general type compared with handling in boxes carried on tractors. Shock loading could well be heavy with relatively small boxes carried on tractors particularly at the front end.

Apart from the experiments on peaches mentioned above, little work has been done on the effect on damage of artificially produced vibrations. Measurements of this sort should complete the line of enquiry on the effect of vehicle vibration on damage, without having to use the potato as a crude instrument for the measurement of acceleration and susceptibility to damage. A preliminary experiment, however, with a bushel box of potatoes on a vibrator that gave a 1 inch vertical movement at a frequency that kept the potatoes moving constantly for 24 minutes, resulted in skinning damage of the following extent:

TABLE VI
PERCENTAGE NUMBER OF POTATOES WITH SKINNING INJURY

Position in box	*Proportion of skin removed*			
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$
Top	56	28	14	2
Bottom	74	16	9	1

Shock loads in small containers

There was more movement in the relatively small container used in the above experiment than would be expected in a ton or even a 5 cwt capacity bin. Studies of handling $\frac{1}{2}$-bushel boxes of Conference pears in the orchard have shown that shocks of 1 and 3 *g* may be expected during the careful stacking of boxes onto a low orchard trailer. When a $\frac{1}{2}$-bushel box was dropped from knee height onto the grassy surface of the orchard, shocks of over 20 *g* were recorded.

Combined Static and Shock Loads

When relatively deep handling units are used there is a danger that the combined effect of static and shock loads at the bottom of the bin may cause damage. Although potatoes are very susceptible to shock loads they can withstand high static loads, and the danger of combined static and shock loads is probably not great. With apples on the other hand, where the limit for static loading is nearly reached in the bottom layers in the majority of commercial bins, combined static and shock loading could be of significance as a cause of damage.

Stage at which Damage Occurs

It is very difficult to obtain an accurate measure of potato damage during the various stages from lifting the crop to the point of sale, due to the variability in susceptibility between individual tubers, the conditions of lifting and handling and human factors affecting the way in which the machinery is used. For this reason it is doubtful if damage surveys can provide reliable comparisons between different handling methods. A detailed study of the movements of individual potatoes, the static loading and shock loads that happen in different conditions, followed up by separate studies of the resistance of the potatoes to static and shock loads, would appear to be more likely to yield quantitative data on the effect of different handling methods on the damage that can be expected. However a number of damage surveys have been made and they give good indications as to the stage at which most of the damage occurs.

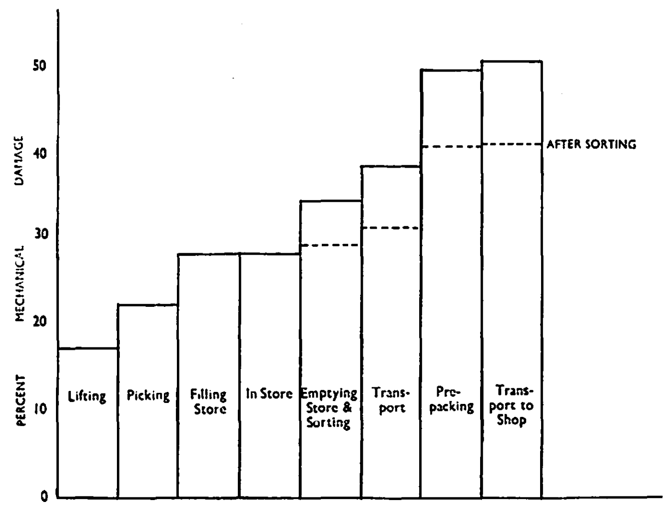


Fig. 2
Potato damage at different stages of handling (Lööw)

A survey by Lööw in Sweden showed that while lifting was the most damaging operation, the potatoes were injured at every stage between the field and the shop, except during storage. After lifting packaging was the most damaging, but the amount of damaged potatoes in the sample was decreased by sorting out the damaged tubers.

Burton and Twiss found 33.5% and 22.8% damage with elevator diggers and spinners respectively, with an additional 16% for transport and store loading. After grading 65.5% of the crop was found to be damaged, with a final 2.5% added during distribution. Working in conjunction with the Kent Farm Institute, it was found by the same authors that potatoes were not immune to damage when transported in pallet boxes on tractors over rough ground at anything over a low speed. Damage was also inflicted during the filling of the boxes by the pickers, who dropped the potatoes from the same height regardless of the height of the sides of the box. It was therefore concluded that a 25-inch deep bin was better than an 18-inch deep bin when filled by hand pickers.

A similar pattern for damage is shown in the case of apples. For example, McMechan and others in British Columbia obtained the following results for the variety McIntosh.

TABLE VII

APPLE DAMAGE AT DIFFERENT HANDLING STAGES
(McMechan *et al.*)

Sample taken from	*Bruise/Score apple*	*Stem punctures/ 100*
Picking bag	6.3	1.2
Bin under tree	12.8	1.8
Bin at loading area	14.7	1.6
Bin on arrival at pack house	15.8	1.8
Bin at pack house after 25 days cold storage	20.9	1.7

Most of the damage occurred during picking and filling the picking bag, and in emptying the picking bag into the bins, but relatively little damage occurred during the 100-yard haul from the tree to the loading area in the orchard, and from the orchard to the pack house.

Nelkin and others working on the transport of fruit in Israel found that, although damage occurred at loading and unloading, the actual travelling by whatever method over a distance of 20 km did not cause any damage.

Methods of Avoiding Damage

Damage prevention lies mainly in the choice of a handling method that gives the least amount of movement of the potatoes or fruit, but the size of unit handled is of considerable importance. Potatoes bouncing on the chain of an elevator digger may be considered as single potato units undergoing a handling process. This is the stage at which much of the damage occurs. Similarly with apples during picking the fruit receive individual treatment. In the picking bag the handling unit is small and damage is high. Potato harvesters are damaging implements largely because they rely on agitation to remove the soil and absence of damage is left to chance. If serious consideration is given to damage prevention, the harvester offers a greater potential for damage prevention than the digger and hand picking, since a large number of separate potato movements are inseparable from the latter method.

The design of the container can influence damage. Containers should protect the commodity handled and not damage it. Of all containers the sack is undoubtedly the worst, as it provides no protection to potatoes and leaves them entirely at the mercy of careless manual handling. In bins, rough timber, projecting corners, and boxes that deform on handling can cause damage. If plywood is used, the glue should not be one that causes staining, while wood preservatives should not taint the fruit.

The choice of the optimum depth and capacity of handling container depends upon many factors. With manual handling, small units such as half and bushel boxes may be expected to result in fruit bruising due to the high shock loading and the large proportion of the fruit being in contact with the timber sides and bottom, although static loads will be low. With bins the methods of filling and emptying must be considered. With hand filling in the field or orchard, depth of bin is of no great consequence as the drop into the bin depends mainly on the picker. When filling trailers or bins from a potato harvester, damage can be minimized by the use of adjustable delivery elevators, provided the elevator has sufficient movement and the design of the box is such that adjustment of the elevator is possible.

Damage due to vibration and shock loads during transport depends upon the springing and damping properties of the vehicle and the speed of travel, and of course on the road surface. It has already been mentioned that the greater the depth of the container the greater the shocks at the surface for a given shock at the bottom, but with shallower containers the surface layers of fruit account for a greater proportion of the bulk, which may result in greater damage. In addition, the combined static and shock loads at the bottom of the container can be a source of damage, particularly for apples where, for fruit at the bottom, the limits for static loading are close with the majority of bins at present in use. For apples a safe depth of container would be about 1½ to 2 feet, while for pears with their variable susceptibility to damage, the safe depth, depending upon variety and storage conditions, is perhaps half that for apples. Potatoes on the other hand can stand high static loads, and here the limits of depth depend more upon problems of ventilation and machine capacity than on considerations of damage.

Injuries can sometimes be prevented by the use of padding, and its use is justified at those points in the handling operation where a rapid movement of the potatoes is unavoidable, e.g., parts of diggers and harvesters, and at the bottom of bins and trailers during filling. In these places the padding should be such that the energy of impact is absorbed, and the potatoes do not rebound like billard balls to double the velocity of impact with the next potato.

Conclusions

Damage to potatoes and fruit is entirely dependent on handling, but the actual process of transport, although it subjects the potatoes to vibration and repeated shocks, does not at the worst lead to very great injury. The frequency and severity of shocks during transport depend, as well as on the road surface, upon the speed and suspension of the vehicle; a well damped suspension appears to be more important than one that is well sprung. A slow-moving vehicle can give a greater number of shocks for a given journey than a faster sprung vehicle.

The method used for filling and emptying the containers has far more influence on the amount of damage. Where fruit or potatoes are moved separately, as in harvesting and sorting operations, damage is at its greatest. Handling in small manual units such as bushel boxes results in high shock loads, and further damage can be caused by prolonged contact with the hard sides. With increased size of container, shock loading becomes of lesser significance, but static and combined static and shock loads become of greater importance and set practical limits for container depth at least for fruit.

REFERENCES

1. BURTON, W. G., TWISS, P. T. G.; 'Survey of wastage of potatoes' A. R. C. Ditton and Covent Garden Laboratories, *Annual Rep.* 1963, 19-20.

2. O'BRIEN, M., CLAYPOOLE, L. L., LEONARD, S. J., YORK, G. K. and MACGILLIVRAY, J. H.; 'Causes of fruit bruising on transport trucks' *Hilgardia* 1963, *35*(6) 113-124.

3. TWISS, P. T. G., 'Quality as influenced by harvesting and storage', 1963, IVINS, J. D. and MILTHORP, F. L., 'The growth of the potato' *Butterworths* 281-290.

4. MCMECHAN, A. D., MAY, K. E., and SUTHERLAND, D. J. 1962, Report of the committee to study fruit handling equipment, British Columbia.

5. LÖÖW, H. 'Mechanical damages to potatoes' *Swedish Institute of Agricultural Engineering*, 1964, Report No. 304.

6. NELKIN, S. et al 'A survey of deciduous fruit picking, sorting, and transport' *Israel Inst. of Prod. Agric. Sect. Rep.* 1958.

DISCUSSION

MR R. M. CHAMBERS (Massey Ferguson U.K. Limited) asked if Table II of the Paper could be extended. The total damage at 26th September was considerably below that of 29th August and this might suggest that farmers should delay harvesting of their potatoes. Referring to Figure 2, Mr Chambers asked whether the methods of assessing damage in Sweden, were similar to those used in the U.K. Could one compare these data with figures from U.K. sources? In reply to the first point Mr Green said that one should not place too much faith in the drop on 26th September shown in Table II. He had extended this for several weeks but he thought he could say no more than that there was a definite rise in susceptibility to damage from 8th August until mid-September, thereafter remaining at a constant high level. One was not justified in saying there was a 'hump'; damage susceptibility simply rose to a maximum and stayed there. Mr Green said he was not certain whether methods of assessment in Sweden were the same as those in the U.K.; he had inserted these figures in order to show the relative position. The point he had tried to make was that most of the damage occurred at the two stages of lifting and packaging respectively. Mr G. S. GRANTHAM (from Lincolnshire) asked if Mr Green had found any great variation in the characteristics of each variety as regards damage, whether rainfall and climatic conditions were relevant and whether the dry-matter of the potato also had any effect. Mr Green replied that some work had been done on the effect of dry-matter, but not yet on the other factors. It was sometimes thought that the higher dry-matter varieties were more resistant to damage than those of low dry-matter content, but this was not certain. The important factor appeared to be the size of starch grains in the cells and in those varieties where there were large starch grains it had been demonstrated that if the potato were subjected to a shock, for example, due to a drop, that the large starch grains moved through the cell wall, disrupting and killing it. There were many factors affecting damage susceptibility of which dry-matter was merely one. Mr Green thought that a slight improvement might be obtained by the choice of a damage resistant variety, but potatoes were treated so roughly, particularly in the harvesting stage, that complete immunity to damage was probably impossible.

MR G. C. MOUAT (Department of Agricultural Engineering, Essex Institute of Agriculture) commented that some years previously a damage index of potatoes had been available. He did not believe that it had proved very satisfactory, but it had tried to give a single figure for damage to the potato crop regardless of whether the damage happened to be severe, not so severe or merely slight. This enabled one to conclude that a particular system of harvesting was either bad or not so bad from the point of view of damage. Mr Mouat asked if the damage index system was a satisfactory measure of damage. If not, was there any alternative system of trying to assess the damage inflicted by harvesting systems, irrespective of whether the damage was severe or just slight? Mr Green apologised for using damage indices on apples in some of the figures shown in his paper. He believed they were useful, but dangerous, and it depended somewhat on how they were used. The potato damage index might have fallen into disuse at present because it tried to put a somewhat arbitrary figure on different types of damage. It took account of things that were basically quite different and then combined them to give one figure; the damage index had been employed very successfully in the measurement of susceptibility to damage. Some work had been done by Dr Lampe in Germany who had produced a device which drove a probe into the potato. The force required to drive this probe into the potato was measured and a good correlation could be obtained between this and the damage index to give quite a measure of the susceptibility to damage of any given crop of potatoes. Mr Green thought, however, that the only really satisfactory method of damage assessment was to study each type of injury separately and consider it in its own light.

MR C. de B. CODRINGTON (Potato Marketing Board) drew attention to Mr Green's suggestion that skinning could perhaps add a certain degree of freshness to early potatoes. He agreed that this was acceptable to the consumer, but on the other hand a good deal of damage occurred and blackening ensued in the following marketing process. Mr Codrington said he would like to think that it was only a matter of 24 hours before the early potatoes reached the market, but he feared it was often much longer. Furthermore, the increased use of plastic bags for marketing caused him to wonder whether the high humidity around the potato in the bag did not increase the rate of blackening or make it more obvious. He would welcome Mr Green's observations on that point. Mr Codrington thought that the damage surveys carried out by the Board and by Twiss and Burton were very significant and even frightening. Expressing his concern about the way damage was estimated, Mr Codrington said his Board had the difficulty of trying to inspect samples of potatoes in the market to determine whether they were marketable or not. Para-cresol tests provided the basis of much of the work, but this test did not give any idea of the intensity of damage; a potato might have a large number of severe blemishes right round it, in which case the subsequent loss to the con-umer in peeling would be much greater than in a tubers with just one small piece knocked out of it. With regard to the design of bins Mr Codrington asked if Mr Green could state whether he understood that the larger the bin or pallet, the greater would be the rate of damage. His Board had gathered experience of using self-unloading trailers, bringing in approximately 1,500 tons of potatoes during the previous season, and he was absolutely horrified that such equipment might come on to the market when very significant amounts of damage were seen to occur with them. On the question of blackening in packs of early potatoes, Mr Green said he could not throw any light on this as it was not something he had studied. On methods of estimating damage, he said in answer both to Mr Mouat and Mr Codrington that he had found no need for a standard method. He had looked for different things on different occasions and if one was interested in internal bruising for example, one would want a different technique from any other for bringing that type of injury to light. Mr Green said he would very much like to have some method of estimating areas of injury, particularly with apples. The methods normally employed relied on some visual estimation which was probably very inaccurate. With regard to the size of bins he believed there were quite a number of interacting factors, but the short answer was 'the bigger the better'. However, there was also the question of the static load at the bottom of a bin and also the fact that contact between the apple and the timber side or bottom was more damaging than fruit-to-fruit contact, which had a bearing on the optimum size and depth of bins; it was a matter of arriving at the right compromise. Mr Green went on to comment that he was concerned about the effect of vibration on consolidation in bins. In the case he had mentioned earlier there was approximately 10% settling. This implied considerably closer packing after vibration, which must inevitably increase the side thrust of the apples on the side of the bin, leading to greater static loads and eventually in the case of fruit such as pears to a greater amount of flats in storing. Concerning bulk loaders, the damage measurements that Twiss had made were rather in favour of them. Mr Green said that he had not made any direct measurements for comparison between these and any other method, but from observation of the way the potatoes were removed from the bulk loader on a moving chain one would expect the potatoes to suffer more damage than if they were handled in bins.

MR C. A. CAMERON BROWN (Electricity Council) asked Mr Green whether he could clarify the sentence in the paper which read '. . . but the amount of damaged potatoes in the sample was decreased by sorting out the damaged tubers'. Mr Green replied that it meant that because obviously damaged potatoes were removed in the process of packaging, the proportion of damaged potatoes remaining in the sample at the time of retail sale was less.

MR C. V. BRUTEY (National Farmers Union) said he was glad that somebody had highlighted the high incidence of damage to potatoes after they left the hands of the farmer and on the way to the shop. He said he believed this was one of the most alarming features of the problem and thought it fair to say that both the farmer and the agricultural engineer were extremely conscious of the position of damaged potatoes. He wondered what could be done to bring home this information and these facts to those responsible for handling the potatoes between the farm and the shop, or more particularly between the wholesaler and the shop. Mr Brutey acknowledged that this was not quite a technical problem but it was important that technical information should be made known as widely as possible; this lay within the function of technical institutions and bodies whose research work brought this information to light. Mr Green agreed that there was considerable scope for avoiding damage during the stage of transport to the shop, but it was not enough to say to the people loading lorries 'be careful'. Possibly it would be preferable to develop a method of handling which would make it impossible for the potatoes to be damaged. The onus should not be on the lorry driver, nor the man loading the lorry; handling was a different matter and it was up to the merchants or whoever was responsible for the transport of potatoes in any particular instance. Mr Green said that it was up to agricultural engineers to develop methods of handling that would minimize damage.

Mr Codrington said he felt the Potato Marketing Board had a responsibility in this direction and it had seriously looked into the problem. Some two years previously a film on potato damage had been distributed and shown on farms and in markets as widely as possible. Some who had seen the film had agreed that damage occurred and that a percentage of loss was suffered and yet they seemed to take no notice of it. Mr Codrington believed it was a question of getting at the man actually handling the crop or whoever was in charge of that man. He believed the majority of the potato crop was, in fact, handled by merchants' own transport and therefore one had to have an identifiable contact. He had only recently heard of a farmer who had seen a lorry driver throwing about sacks of his potatoes in a manner which caused him to assume that they were being damaged. The farmer returned the lorry to the merchants with a message that he would not permit his potatoes to be delivered on that lorry; the merchants must send somebody else who would take more care of them. To take a wider view of the situation, went on Mr Codrington, it was unfortunate that most of the main markets, particularly in the London area, but also elsewhere in the country, were absolutely archaic and had few means of mechanical handling. Some new markets had been built where palletization was widely adopted, Coventry being one example. This would be one of the greatest aids, particularly if the potatoes were going to be packed and dressed out at more centralized depots. They would be loaded on one-ton pallets which would in turn be loaded on to the lorry. If they had to go into the market they could be handled there by fork lift trucks and thence to the retailer where they could be taken off the pallets. Mr Codrington said he sincerely hoped this would come about on a wider scale because he believed it was one of the best things that could happen. It was really a matter of money—while farmers could sell potatoes that were damaged, they would not be so concerned as they would when people became more discriminating and refused to pay for damaged potatoes. Finally, Mr Codrington thought that acknowledgement should be paid to the work that had been started by the Horticultural Marketing Council which, unfortunately, was now no longer in existence. Mr Green commented that he thought the aim should be to eliminate the sack as a handling unit as quickly as possible.

Mr R. M. Chambers commented that he occasionally peeled potatoes and he estimated that to peel away the damage in most cases did not sacrifice more than about 5% of the potato. If the Potato Marketing Board insisted on undamaged potatoes being supplied and charged 10% more, it became uneconomical. He suggested that a level must be found somewhere and, of course, the best way of eating potatoes was the Irish way—in their jackets. If one could obtain them from English growers undamaged, this should be done.

THE PRESIDENT, bringing the discussion to a close, commented that he had always thought the method of eating potatoes advocated by Mr Chambers was, in fact, the real English way.

In a subsequent written contribution, Mr C. V. Brutey recalled that, during the discussion, he had drawn attention to the high incidence of damage to potatoes during the course of transport and delivery (i.e. after leaving the jurisdiction of the farmer). His intention had been to point out that farmers and agricultural engineers were at least conscious of this problem and making efforts to overcome it, and that the detailed information presented at this Open Meeting might with advantage be brought to the notice of those responsible for the transport and handling of potatoes. Unfortunately, continued Mr Brutey, this had been interpreted by the speaker and others taking part in the discussion as a suggestion that the N.I.A.E. should address itself to lorry drivers and market porters. This was not quite what he had intended. There were responsible institutions and other organizations concerned both with the technical and the management aspects of transport and Mr Brutey said he felt sure that their members would find the specialized information put before this Open Meeting to be of great interest and value.

Index to Advertisers

ELECTIONS AND TRANSFERS

Approved by Council at its meeting on 12th November 1964

ELECTIONS

Member	*Overseas*	Frank, R.	Germany
Associate Member		Bellhouse, R. L.	Northumberland
		Johnson, H. B.	Warwicks
		Tilbury, D. W.	Cornwall
Associate		Christie, R.	Leics
		Croome, M.	Surrey
		Fenton, S. H.	Westmorland
		Hunt, G. L.	Warwicks
		Jones, J. E.	Montgomery
		Lupton, J. R.	Notts
		Mundell, P. F.	Herts
		Patterson, T. W.	Berks
		Webber, J. C.	Warwicks
		Williamson, A. P.	Northumberland
	Overseas	Duncan, R. D.	West Indies
	Overseas	C. G. White	Ceylon
Graduate		Grey, E. A.	Leics
		Hattersley, R. M.	Staffs
		Henderson, J. R. G.	Ches
		Kidd, M. A.	Wilts
		Randall, R. C.	Wilts
		Robinson, K.	Glam
		Samarasinghe, D. K.	Lincs
		Wilson, J.	Devon
	Overseas	Opoku, D. K.	Ghana
	Overseas	Patel, V. C.	Germany
	Overseas	Rooprai, A. S.	India
	Overseas	Thakrar, H. G.	Zambia

TRANSFERS

Member		Hargreaves, D. B.	Ches
	Overseas	Atkinson, J. A.	Australia
Associate Member		May, B. A.	Beds
		Munson, J. P. J.	Essex
		Watson, P. S.	Oxon
Graduate		Bomford, P. H.	Worcs
		Garland, P. J.	Essex
		Harding, J. S.	Pembs
		Rowling, M. S.	Essex
	Overseas	Beeny, J. M.	Malaysia

ELECTIONS AND TRANSFERS *(continued)*

Approved by Council at its meeting on 4th February 1965

ELECTIONS

Member	.. .. ..	Bone, G. W.	Suffolk
	Overseas ..	Wehsely, K.	Germany
Associate Member	.. .. ..	Cruttenden, V. J.	Kent
		Hocking, K. J.	Beds
		Norcliffe, K. A.	Yorks
		Reaves, R. W.	Warwicks
Associate	.. .. ..	Gentles, W. H.	Yorks
		Gill, R. H.	Notts
Graduate	.. .. ..	Burcombe, R. J.	Bristol
		Crallan, B. R.	Lincs
		Carrick, G. S.	Northants
		Dines, R. D.	Hants
		Painting, R. J.	Oxon
		Pettit, R. F. R.	Oxon
		Storr, K. A.	Lincs
		Webb, B. W.	Bristol
		Whyte, D. N.	Norfolk
Student	.. .. ..	Akinsete, E.	Ayr
		Bartle, J. A. G.	Essex
		Bateman, G. H.	Surrey
		Bradford, S. P. J.	Herts
		Clark, J. A. L.	Essex
		Cousins, S. B. A.	Essex
		Giddings, R. M.	Beds
		Hayward, A. R.	Essex
		Huie, E. A. C.	Beds
		Kellaway, D. H.	Beds
		Linton, B.	Essex
		Notley, P. M.	Berks
		Philips, P. R.	Northants
		Roche, C. J. E.	Beds
		Shepherd, W. R.	Beds

TRANSFERS

Associate Member	.. .. ..	Brain, D. M.	Devon
		Walker, D.	Ches
Graduate	.. .. ..	Chick, D. C.	Co. Durham
		Corrie, W. J.	Lancs
		Elwes, E. H.	Glos
		Low, J. P.	Cornwall
		Pearson, M. J. C.	Cambs
		Statham, O. J. H.	Beds
	..	Tucker, N. G.	Warwicks
	Overseas ..	Gordon, D. J.	Australia
	Overseas ..	Moffat, D. I.	Zambia

Abbreviations and Symbols used in the Journal

a	year
A or amp	ampere
ac	acre
a.c.	alternating current
atm	atmosphere
b.h.p.	brake horse-power
bu	bushel
Btu	British Thermal Unit
cal	calorie
c.g.	centre of gravity
C.G.S.	centimetre gramme second
cm	centimetre
c/s	cycles per second
cwt	hundredweight
d	day
dB	decibel
D.B.	drawbar
d.c.	direct current
°C, °F, °R	degree Celsius, Fahrenheit, Rankine
deg	degree (temperature interval)
dia	diameter
doz	dozen
e.m.f.	electromotive force
ft	foot
ft^2	square foot (similarly for centimetre etc.)
ft lb	foot-pound
G.	gauge
g	gramme
gal	gallon
gr	grain
h	hour
ha	hectare
Hg	mercury (pressure)
hp	horse-power
h	hour
in.	inch
in^2	square inch
i.d.	inside diameter
kWh	kilowatt hour
	litre
lb	pound
lm	lumen
m	metre
max.	maximum (adjective)
m.c.	moisture content
m.e.p.	mean effective pressure
mile/h	miles per hour
mill.	million
min	minute
min.	minimum (adjective)
o.d.	outside diameter
o.h.v.	overhead valve
oz	ounce
Ω	ohm
pt	pint
p.t.o.	power take-off
qt	quart
r	röntgen
r.h.	relative humidity
rev	revolutions
s	second
s.v.	side valve
S.W.G.	standard wire gauge
t	ton
V	volt
v.m.d.	volume mean diameter
W	watt
W.G.	water gauge
wt	weight
yd	yard
>	greater than
≯	not greater than
<	less than
≮	not less than
∝	proportional to
~	of the order of
° ′ ″	degree, minute, second (of angles)

The above abbreviations and symbols are based mainly on B.S. 1991 (Part 1), 1954

Printed by Eaton Press Ltd., Liverpool