JOURNAL AND PROCEEDINGS OF THE

INSTITUTION OF AGRICULTURAL ENGINEERS

VOL. 19 NO. 3 - OCTOBER 1963

Salisbury

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All over the world tractors, dumpers and commercial vehicles, as well as many of the world's finest and fastest cars, rely on Salisbury hypoid axles and gears, for complete dependability in transmission.

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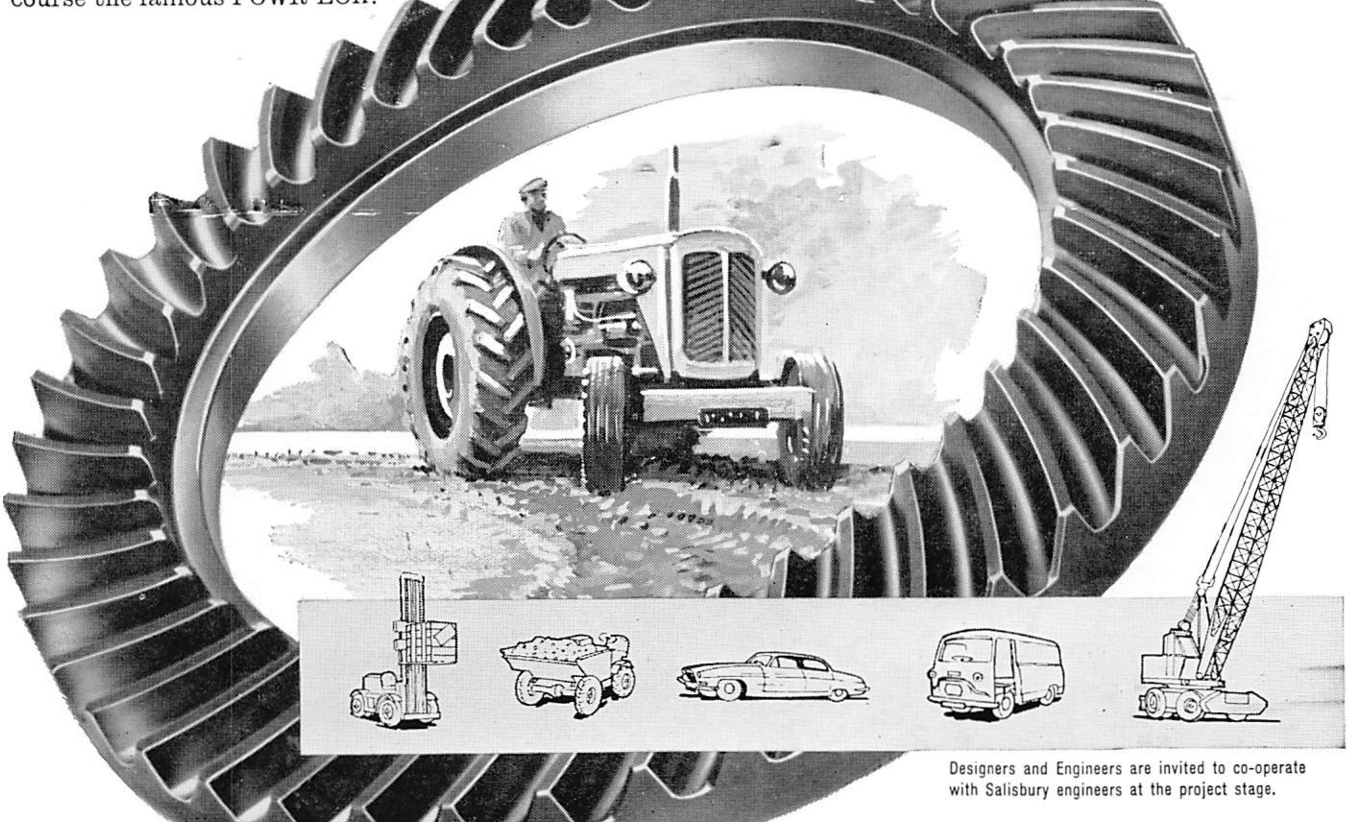

Designers and Engineers are invited to co-operate with Salisbury engineers at the project stage.

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JOURNAL AND PROCEEDINGS OF THE INSTITUTION OF AGRICULTURAL ENGINEERS

VOLUME 19 - NUMBER 3 - OCTOBER, 1963

CONTENTS

INSTITUTION NOTES

The views and opinions expressed in Papers and individual contributions are not necessarily those of the Institution. All Papers in this Journal are the copyright of the Institution

Past Presidents' Badges

Following the presentation of a Presidential Badge to the Institution by Shell-Mex and B.P. Limited in 1962, the Company has now prepared Past Presidents' Badges, and these were received on behalf of the Institution by the President at the Open Meeting at the Royal Society of Arts on October 17th. Council wishes to record appreciation of this yet further evidence of the support of the Company for the work of the Institution.

Award of Johnson Medal

It is with great pleasure that Council has approved the award of the Colonel Johnson Medal to Kenneth McLean (Essex Institute of Agriculture), the outstanding candidate in the 1963 Final Examination for the National Diploma in Agricultural Engineering. The Medal was last awarded in 1958 ; the winner must be of an exceptionally high standard, securing marks of near distinction level in all subjects of the examination. The Medal was presented to Mr. McLean by the President at the Open Meeting on October 17th.

LONDON OPEN MEETING, JANUARY 30th, 1964

The second all-day London Open Meeting of the 1963/64 Session will be held at the Royal Society of Arts, John Adam Street, London, W.C.2, on Thursday, January 30th, 1964, commencing 10.45 a.m. Details of the Programme appear on the back cover of this issue.

Agricultural Engineer Required for Columbia

The International Labour Organisation, which is responsible for carrying out a United Nations Special Fund Project in Columbia, requires an expert in the use of agricultural machinery to be stationed in Bogota. The main duties of the expert will be to advise on the problems raised in the country by the use of the different types of agricultural machines and to make recommendations concerning the training of agriculturalists in the use of machinery and the training of other personnel in their operation. Full details may be obtained from the Assistant Secretary.

Institution Representative in New Zealand

Mr. M. W. Cross, M.I.Agr.E., of the Massey Agricultural College, New Zealand, has been appointed Institution Representative in that country.

Course for Designers

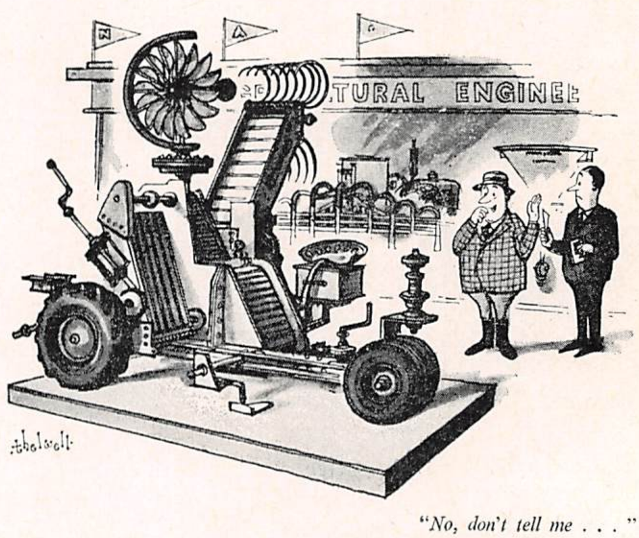
The School of Welding Technology has arranged a course for December, 1963, for designers of agricultural machinery and for others who are concerned with weld problems and techniques. Details of the course are enclosed with this issue. The President will be Guest of Honour at the Inaugural Dinner of the Course.

1963 Examinations

The 1963 N.D.Agr.E. and Membership Examinations were again held at the Essex Institute of Agriculture and Rycotewood College, Oxon., by kind permission of the respective Principals, Mr. B. H. Harvey and Mr. C. A. Goodger. The results appear on pages 106 and 107.

New Examination Syllabus

The Examination Board has approved the introduction of a paper in Workshop Technology and Engineering Drawing into the Institution Examination for Membership. Candidates will be able to offer this subject for the first time in 1964 as an alternative to Principles of Farm Mechanization Management.



"No, don't tell me . . ."

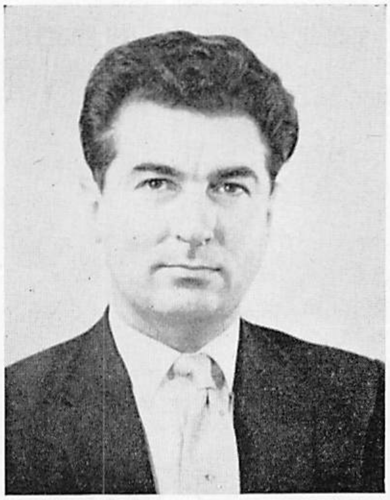
Reproduced by permission of PUNCH

MR. J. K. BENNETT APPOINTED SECRETARY

Council announce the appointment of Mr. Jon Keith Bennett, F.C.C.S., F.R.S.A., M.I.O.M., as Secretary of the Institution of Agricultural Engineers, in succession to the late Mr. R. E. Slade.

Mr. Bennett, who is 37, has been Secretary of the Institute of Road Transport Engineers for the past 10 years. During that time he has been closely associated with a number of major projects, including the foundation of the Registered Student grade in 1955 and the development of the Institute's proposed corporate membership examination scheme. He was intimately concerned in the acquisition of the new Headquarters building in Kensington in 1961. With his keen interest in the Institute's regional development, he has been instrumental in the formation of eight Centres and Groups. Thus, he has seen the Centre network double itself in ten years, and membership as a whole increase by around 40 per cent. In the editorial field, Mr. Bennett has played a large part in modernising the appearance and style of the Institute's publications, particularly the Journal. A keen adherent of office mechanisation, he has done much to streamline the Institute's internal and domestic administration.

In 1959–61, Mr. Bennett acted as Secretary to the Joint Study Group for Road Transport Materials Handling, sponsored by the National Council for Materials Handling. During 1961–63 he was Secretary to the I.R.T.E. Vehicle Exhaust Study Group.



Mr. Bennett began his career in the Ministry of Agriculture and then underwent his National Service, part of which was spent in Egypt and Palestine as an R.A.S.C. officer. After that, he held an administrative post with an international firm of brokers in the City of London, remaining with them until his appointment as I.R.T.E. Secretary.

Mr. Bennett will take up his new appointment on Monday, December 9th, 1963.

SCHOLARSHIP AWARDS

The Institution announces the following Scholarship Awards tenable during the 1963/64 final year's course of study for the National Diploma in Agricultural Engineering at the Essex Institute of Agriculture or the West of Scotland Agricultural College.

Dunlop Scholarship Award

The Dunlop Scholarship has been awarded to Mr. Robert Lemon, aged 23, of the College of Aeronautical and Automobile Engineering, Chelsea, London, S.W.3.

Mr. Lemon received 2½ years' training at the Chelsea College, leading to the award of the College Diploma in Agricultural Engineering and to exemption from the Intermediate Examination of the National Diploma in Agricultural Engineering. He is a native of Arnside, Westmorland, and in addition to his engineering training has received a year's training in agriculture at the Cumberland and Westmorland Farm School.

Shell-Mex & B.P. Bursary Awards

The recipients of these awards are both returning to full-time education to specialise in agricultural engineering.

Mr. Peter Garland, aged 23, of Hadleigh, Suffolk, who was born in South America, gained a Second Class National Diploma in Agriculture in 1960 after an approved course of study at the Essex Institute of Agriculture. Since 1960 he has obtained wide farming experience.

Mr. Neville Tucker, of Midford, Bath, aged 23, gained a Second Class National Diploma in Agriculture in 1961 following two years' approved study at the Seale Hayne Agricultural College. Mr. Tucker was employed as a Farm Inspector and Advisor by a dairy during the past year.

BRANCH OFFICERS AND MEETINGS

The Programme Card giving complete details of Open Meetings for 1963–64 will be circulated with the December edition of the Journal.

EAST ANGLIAN BRANCH

Chairman :
J. Shewring, N.D.Agr.E., M.I.Agr.E.
Vice-Chairmen :
W. G. Cover, M.I.E.E., M.I.Agr.E.
A. H. Neale, A.M.I.Agr.E.
Committee :
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E. C. Claydon, N.D.Agr.E., M.I.Agr.E.
J. H. Cock, B.Sc. (Agric.), A.M.I.Agr.E.
U. G. Curson, A.M.I.Agr.E.
P. G. Day, N.D.A., N.D.Agr.E., A.M.I.Agr.E.
G. D. Eglington, A.I.Agr.E.
A. R. Ford, A.M.I.Agr.E.
F. L. Gammon, M.I.Agr.E.
G. C. Gooderham, A.M.I.Agr.E.
J. M. Harston, A.M.I.Agr.E.
J. C. Mann, M.A., A.I.Agr.E.
R. F. Norman, M.Sc. (Agric.Eng.), B.Sc. (Agric.), A.M.I.Agr.E.
F. C. Orchard, M.I.Agr.E.
T. J. Rivers, A.M.I.Agr.E.
N. E. Salmon, A.I.Agr.E.
C. E. Westrip, M.I.Agr.E.
Honorary Secretary :
C. V. H. Foulkes, B.Sc. (Agric.), C.I.Agr.E., c/o County Education Offices, Stracey Road, Norwich. Nor. 49A.

November 13th, 1963
CONFERENCE, 10.15 a.m. to 5 p.m., " Grain Handling and Storage," at Assembly House, Norwich.
February 7th, 1964
ANNUAL DINNER, 7.30 p.m., at The Royal Hotel, Norwich. Following Dinner, Mr. W. J. Priest, President, will speak on the future plans of the Institution.
March 12th, 1964
ANNUAL GENERAL MEETING, 7.30 p.m., at Assembly House, Norwich. Following the business of the meeting, Professor T. A. Bennet-Clark, Dean of the School of Biological Sciences, University of East Anglia, will speak on the plans of the University in relation to agricultural science.

EAST MIDLANDS BRANCH

Chairman :
W. J. Whitsed, M.I.Agr.E.
Vice-Chairman :
L. West, B.Sc. (Eng.), A.M.I.Agr.E.
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Committee :
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E. F. Beadle, A.I.Agr.E.
H. P. Crapp, B.Sc., A.I.Agr.E.
R. Dalton, A.I.Agr.E.
B. Farrar, A.M.I.Agr.E.
C. L. Fox, A.M.I.Agr.E.
G. Hows, A.M.I.Agr.E.
R. H. Miers, B.Sc., A.M.I.C.E., M.I.Agr.E.
P. A. L. Orbell, N.D.A., M.R.A.C., A.I.Agr.E.
C. C. Rainthorpe, C.I.Agr.E.
R. Russell, A.M.I.Agr.E.
Honorary Secretary :
D. G. Wynn, A.M.I.Agr.E., c/o Allis Chalmers (G.B.), Ltd., Essendine, Stamford, Lincs.

September 18th, 1963
VISIT to Appleby-Frodingham Steel Company, Scunthorpe, to see factory. 10 a.m., all day.
October 23rd, 1963
PRESIDENTIAL ADDRESS, " Achievement and Anticipation," by W. J. Priest, M.I.Agr.E., at 7.30 p.m. at Angel and Royal Hotel, Grantham.
November 11th, 1963
CONFERENCE, " Tractors of Today and Future Tractor Developments," 9.45 a.m., at Nottinghamshire Farm Institute, Brackenhurst. Speakers : W. S. Hockey, T. C. D. Manby, B.Sc., M.Sc., H. J. Nation, B.Sc., A.M.I.Mech.E., P. E. Gallop.
January 22nd, 1964
PAPER, " Land Drainage," by R. H. Miers, B.Sc., A.M.I.C.E., 7.30 p.m., at Riseholme Farm Institute, Riseholme, Lincoln.
February 26th, 1964
PAPER, " The Testing of Prototype Implements," by P. Hebblethwaite, B.Sc., N.D.A., M.S., 7.30 p.m., at Allis Chalmers Canteen, Essendine.

WEST MIDLANDS BRANCH

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Vice-Chairman :
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Honorary Treasurer :
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Committee :
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J. M. Chambers, M.I.Mech.E., M.I.Agr.E.
R. M. Chambers, B.Sc., B.Agr., M.I.Agr.E.
M. G. Clough, B.Sc. (Agric.), M.Sc. (Agric.Eng.), A.M.I.Agr.E.
E. S. Ekers, A.M.I.Agr.E.
L. P. Evans, N.D.Agr.E., Grad.I.Agr.E.
B. A. F. Hervey-Bathurst, B.A. (Cantab.), M.R.A.C., A.I.Agr.E.
D. W. Knight, A.I.Agr.E.
E. H. Mander, A.I.Agr.E.
E. W. Orchard, M.I.Agr.E.
D. B. Purchas, A.M.I.Agr.E.
R. S. Sargent, A.M.I.Agr.E.
L. E. Summerfield, M.I.Agr.E.
F. D. Swift, A.M.I.Agr.E.

Honorary Secretary :
A. D. Starley, A.M.I.Agr.E., 24, Hearsall Court, Broad Lane, Coventry, Warwicks.

All Meetings to be held at 7.30 p.m. in Room 118, College of Advanced Technology, Gosta Green, Birmingham, unless otherwise stated.

September 30th, 1963
PAPER, " Renovation and Development of Permanent Pasture," by W. Davies, D.Sc., of the Grassland Research Institute.

October 28th, 1963
PAPER, " Agricultural Machinery Requirements of the Newly Developing Countries," by S. J. Wright, M.A., Agricultural Advisor, The Ford Motor Co., Ltd.

November 25th, 1963
PAPER, " Force Measurement in Agricultural Engineering," by A. R. Reece, B.Sc., M.Sc., A.M.I.Mech.E., A.M.I.Agr.E., of King's College, Newcastle-upon-Tyne.

January 6th, 1964
PAPER, " The Four-Wheel Drive Tractor employed in Agriculture," by Lt.-Colonel P. Johnson, C.B.E., D.S.O., M.I.Mech.E., Hon.M.I.Agr.E., of Roadless Traction, Ltd.

February 3rd, 1964
FORUM, " The Economics of Mechanisation, the Farmer's, Economist's and Banker's Points of View," at 7 p.m., Room G7, College of Advanced Technology, Gosta Green. Speakers : G. Pain, Professor D. K. Britton, J. Howard Morgan.

March 2nd, 1964
SHORT PAPERS EVENING. " The Possible Effects of Future Applications on the Design of Agricultural Tractors and Machinery," by L. Evans, N.D.Agr.E., Massey Ferguson, U.K., Ltd. ; " Towaıds Mechanisation of Livestock Services," by S. Smith, N.D.Agr.E., New Idea Farm Equipment, Ltd. ; " Some Facets Relating to the Soil Mechanics of the Driving Wheel," by K. M. Thomas, The Goodyear Tyre Co.

April 3rd, 1964
ANNUAL GENERAL MEETING AND DINNER. A.G.M., 6.30 p.m. ; Annual Dinner, 7.30 p.m. At The Chadwick Manor Hotel, Knowle, Warwickshire.

May 2nd, 1964
SPRING OUTING, 10.45 a.m. to 5.15 p.m. Farm visit to the University of Nottingham, School of Agriculture, Sutton Bonington, Loughborough.

October 8th, 1963
AUTUMN OUTING, 11 a.m. to 5 p.m. Works visit to The British Timken Division of the Timken Roller Bearing Company, Duston, Northampton.

WESTERN BRANCH

Chairman :
T. Sherwen, M.I.Mech.E., M.S.A.E., M.I.Agr.E.

Vice-Chairman :
A. J. Bradshaw, N.D.Agr.E., A.M.I.Agr.E.

Honorary Treasurer :
A. W. Falconer, N.D.Agr.E., A.M.I.Agr.E.

Committee :
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H. L. Harrison, N.D.Agr.E., A.M.I.Agr.E.
W. L. Hearle, A.M.I.E.E., A.M.I.Agr.E.
A. J. Marshall, A.M.I.Agr.E.
G. Molony, A.I.Agr.E.
B. Stocks, A.I.Agr.E.
L. T. Weston, M.I.Agr.E.

Honorary Secretary :
H. Catling, N.D.Agr.E., A.M.I.Agr.E., Engineering Department, Royal Agricultural College, Cirencester, Glos.

October 16th, 1963
PAPER, " Tower Silos and Mechanised Feeding Systems," by C. Culpin, O.B.E., M.A., Dip.Agric., M.I.Agr.E., N.A.A.S., Liaison Unit, N.I.A.E., at 7.30 p.m. at Hare and Hounds Hotel, Westonbirt, nr. Tetbury, Glos.

October 30th, 1963
PRESIDENTIAL ADDRESS, " Achievement and Anticipation," by W. J. Priest, M.I.Agr.E., at 7.30 p.m. at Hare and Hounds Hotel, Westonbirt, nr. Tetbury, Glos.

February 19th, 1964
PAPER, " The Mechanical Handling of Farm Materials," by J. E. Kennett, M.A., Kennett Handling Equipment, Ltd., at 7.30 p.m. at The George Hotel, Trowbridge, Wilts.

March 18th, 1964
VISIT to Berkeley Nuclear Power Station, Berkeley, Glos., at 2.15 p.m.
PAPER, " Farm Wiring and Installation of Electrical Equipment," by R. A. Bayetto, M.I.Agr.E., Rural Electrification Officer, Electrical Development Association, at 7.30 p.m. at Electricity House, Colston Avenue, Bristol, 1.

SOUTH-WESTERN BRANCH

Chairman :
G. A. Iles, A.M.I.Agr.E.

Vice-Chairman :
R. Zeale, A.M.I.Agr.E.

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Committee :
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K. M. Base, N.D.A., N.D.P.H., A.M.I.Agr.E.
L. B. Ellis, A.M.I.Agr.E.
R. Frost, N.D.A., A.I.Agr.E.
M. G. Harris, A.I.Agr.E.
J. A. C. Weir, N.D.A., M.I.Agr.E.
E. L. Williams, M.C., M.I.Agr.E.

Honorary Secretary :
J. B. Paterson, N.D.A., A.M.I.Agr.E., Seale-Hayne Agricultural College, Newton Abbot, Devon.

All Meetings will commence at 7.30 p.m.

October 9th, 1963

FORUM, Joint Meeting with S.W. Branch, Institute of Welding Panel: G. A. Iles, Western Engineering (Delabole), Ltd.; L. J. Huart, Chief Welding Engineer, Bristol Aerojet, Ltd.; R. B. Whalley, Man. Dir., Inspection Services, Ltd.; L. B. Smith, British Oxygen Co., Ltd. Chairman, E. M. Wilson, M.Inst.W. At Exeter Technical College, Hele Road, Exeter.

November 21st, 1963

DISCUSSION, "Close Row Drilling." Speakers: P. Cundy, R. Cundy & Sons (Farms), Ltd.; R. C. Honey, Reg. Tech. Advisor, Fisons Fertilizers; J. G. Barker, Viking Machinery, Ltd., Ivybridge. At Seale-Hayne Agricultural College, Newton Abbot.

February 21st, 1964

PAPER, "Machinery Testing," by D. I. McLaren, B.Sc., M.I.Agr.E., National Institute of Agricultural Engineering, at South-Western Electricity Board Demonstration Hall, The Parade, Taunton.

March 19th, 1964

DISCUSSION, "Safety," at Agriculture House, Queen Street, Exeter. Speakers to be arranged.

April 9th, 1964

ANNUAL GENERAL MEETING AND DINNER, at University Staff Club, Knightley, Streatham Drive, Exeter.

NORTHERN BRANCH

Chairman:
J. R. Whitaker, N.D.Agr.E., A.M.I.Agr.E.

Vice-Chairman:
G. R. Winter, A.M.I.Agr.E.

Honorary Treasurer:
G. R. Winter, A.M.I.Agr.E.

Committee:
A. C. Ayton, A.M.I.Agr.E.
J. R. Bell, A.I.Agr.E.
R. C. Bramwell, A.I.Agr.E.
J. U. Charlton, A.M.I.Agr.E.
H. Howcroft, A.M.I.Agr.E.
W. R. Lawson, A.I.Agr.E.
C. Moor, A.I.Agr.E.
J. L. Storey, A.I.Agr.E.
B. D. Witney, Grad.I.Agr.E.

Honorary Secretary:
H. B. Huntley, M.I.Agr.E., 4, Southwood Gardens, Kenton, Newcastle-upon-Tyne, 3.

All Meetings will commence at 7 p.m.

October 14th, 1963

PAPER, "Materials Handling on the Farm," by I. J. Fleming, B.Sc., A.M.I.Agr.E., Scottish Agricultural Industries, Aberdeen, at North-Eastern Electricity Board Headquarters, Carliol House, Newcastle-upon-Tyne, 2.

November 11th, 1963

DISCUSSION, "Harvesting, Drying and Storage of Grain," at N.F.U. Headquarters, "Holmwood," Clayton Road, Newcastle-upon-Tyne, 2.

December 9th, 1963

PAPER, "Tractor Testing," by T. C. D. Manby, B.Sc., M.Sc. (Eng.), M.I.Agr.E., National Institute of Agricultural Engineering, Silsoe, at N.F.U. Headquarters, "Holmwood," Clayton Road, Newcastle-upon-Tyne, 2.

January 13th, 1964

PAPER, "Developments in Crop Spraying Machines and Techniques," by R. F. Norman, B.Sc. (Agric.), M.Sc. (Ag.Eng.), A.M.I.Agr.E., Messrs. Fisons Farmwork, Ltd., at Carliol House, Newcastle-upon-Tyne, 2.

February 10th, 1964

DISCUSSION, "Farm Effluent Disposal," at N.F.U. Headquarters, "Holmwood," Clayton Road, Newcastle-upon-Tyne, 2.

March 9th, 1964

ANNUAL GENERAL MEETING, at N.F.U. Headquarters, "Holmwood," Clayton Road, Newcastle-upon-Tyne, 2. Details to be announced later.

YORKSHIRE BRANCH

Chairman:
J. C. Turner, A.M.I.Agr.E.

Vice-Chairman:
J. H. Nicholls, A.M.I.Agr.E.

Committee:
H. E. Ashfield, M.I.Mech.E., M.I.Agr.E.
G. G. Baldwin, M.A. (Eng.) (Cantab.), M.A.S.A.E., M.I.Agr.E.
G. A. S. Frank, A.M.I.Agr.E.
T. H. E. Harrison, B.Sc. (Agric.) (Dunelm), M.Sc. (Agric.Eng.) (Dunelm), G.I.Agr.E.
J. M. Reyner, A.M.I.Agr.E.
D. A. Smith, A.M.I.Agr.E.
D. McD. Walker, A.M.I.Agr.E.

Honorary Secretary and Treasurer:
E. D. Frost, A.I.Agr.E., East Riding Institute of Agriculture, Bishop Burton, Beverley, East Yorks.

(Commencing at 7.30 p.m. at the Strafford Arms Hotel, Wakefield.)

October 18th, 1963

PAPER, "Know Your Enemy—Corrosion," by H. E. Wise, B.Sc., A.M.I.Chem.E., Senior Lecturer, Hull College of Technology.

November 29th, 1963

PAPER, "Recent Developments in the Application and Use of Timber," by W. E. Browning, Regional Officer, The Timber Research & Development Association.

Further details of programme to be announced later.

SCOTTISH BRANCH

Chairman:
D. W. Garvie, B.Sc. (Eng.), M.I.Agr.E.

Senior Vice-Chairman:
I. J. Fleming, B.Sc. (Agric.), A.M.I.Agr.E.

Junior Vice-Chairman:
A. M. Russell, B.Sc. (Agric.), A.M.I.Agr.E.

Immediate Past Chairman:
T. McLaughlin, A.M.I.Agr.E.

Scottish Representative on Council:
W. J. West, B.A., Dip.Agric., M.I.Agr.E.

Continued on page 91

TRACTION PROBLEMS OF AGRICULTURAL TRACTORS

by A. SENKOWSKI,* A.M.I.M.E., M.S.A.E., M.I.Agr.E.

A Paper presented to a Joint Meeting of the East Midlands, West Midlands and Yorkshire Branches in March, 1960.

IN January, 1959, a Paper was presented at a Meeting of the Institution under the title " Ground Adhesion Problems of Wheeled Agricultural Tractors." Much new work has been published on this and associated " off the road locomotion " problems, which has encouraged me to re-write the first part of the Paper, mostly in the light of Mr. M. G. Bekker's articles and his latest book. Full notice has also been taken of the contributions to the discussion on the Paper made by Messrs. A. R. Reece, P. H. Bailey, W. M. Catchpole, D. Manby, Col. P. Johnson and others.

Thrust

This is the principal factor. The thrust " H " is produced by the reaction of the shear strength of the soil against the tangential force exerted at the tyre contact area. A " Shear Box " (Fig. 1) permits us to measure this most important property of the soil.

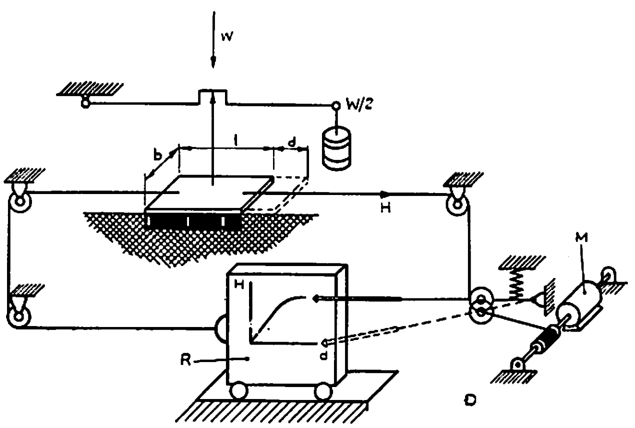

FIG. 1.

Typical results representing various soil samples are plotted in two ways in the diagrams shown on Fig. 2. Each left diagram shows unit shear stresses as a function of the longitudinal displacement of the top shear plate for three arbitrarily chosen but constant vertical unit loads " p." Each corresponding right-hand diagram shows the maximum soil shear strength as a function of varying vertical loads " p." The top pair of curves is for a dry cohesive average soil. The next lower pair is for a wet, cohesive soil ; the third pair for a dry, well settled sand, and the last is for a dry, loose sand.

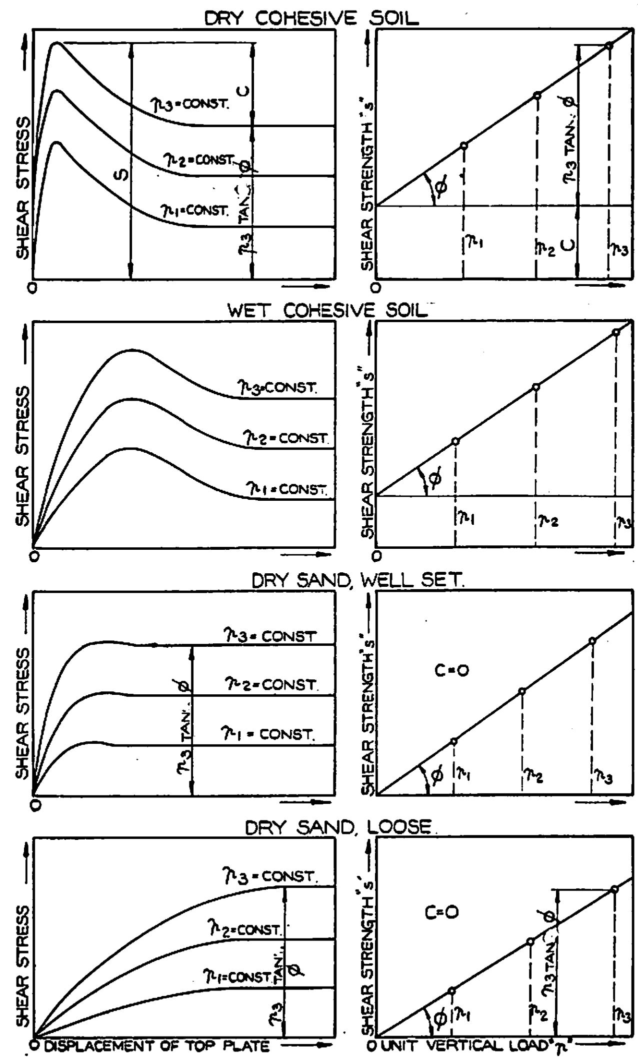

FIG. 2.
Söhne, " Grundlagen der Landtechnik," Heft 12/1961,

The right-hand curves can be all expressed by Coulomb's classic formula :

$$s = C + p \tan \phi$$

where s = Shear strength.
ø = Internal angle of friction.
p = Unit vertical load.

The following comments relate to these curves :

(1) The shear strength of an average agricultural soil is derived from a combination of its cohesive strength " C " (this property being similar to the tensile

---

* Harry Ferguson (Research), Ltd.

strength of conventional engineering materials) and its internal angle of friction (tan ø being the equivalent of the conventional coefficient of friction " μ " between two solid bodies).

Sandy soils derive their shear strength only from the internal friction tan ø (multiplied by the vertical load applied), cohesion " C " being " o." Wet clays, not shown on the diagrams, have a shear strength = " C," independent of vertical load. In extreme cases they have no internal friction and the term " p " tan ø becomes " o."

(2) Soils cannot produce shear strength reactions without some displacements between the ground and the shearing member ; *i.e.*, the wheel or track. This displacement is slip.

(3) Full advantage of the maximum shear strength of average agricultural soils can be taken only at one particular optimum magnitude of ıelative displacement between ground and wheel. Increasing this displacement (or slip) further reduces the shear strength available and also maximum traction.

Sandy soils behave differently and do not show any pronounced optimum points on the shear strength *v.* displacement curves.

In extreme cases of loose, dry sand the shear strength (and traction) increases assymptotically up to tractor stall, obviously with an appalling affect on efficiency.

Wet frictionless clays do not show any practical variation of shear strength at varying displacements (slips). They also show a marginal or no increase of " s " at increased vertical pressure, as angle ø is close to or equal " o."

(4) Increasing the vertical unit load " p " (load on wheel) increases the shear strength " s " of the soil and consequently also the maximum available gross thrust " H " in all conditions except on frictionless soils where ø = 0.

Summing up, we can say that the physical laws determining the variation of soil shear strength " s " are simple and easy to apply.

Practical apparatus to measure " C " and ø in the field is in existence.

Transmission of Forces between Tyre and Ground

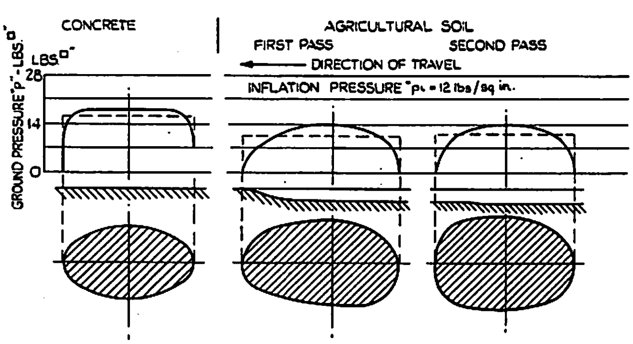

FIG. 3.
Söhne, " Grundlagen der Landtechnik," Heft 3/1952.

The diagram Fig. 3 gives a fair idea of the distribution of the vertical load between a smooth tyre and the ground for concrete and on average soil. The thick curves show the distribution in the longitudinal centre plane. Various factors like load, inflation pressure, carcass stiffness, cleat pattern and soil properties influence the shapes shown. Since our main interest is with traction, more will be said in the section dealing with Travel Resistance.

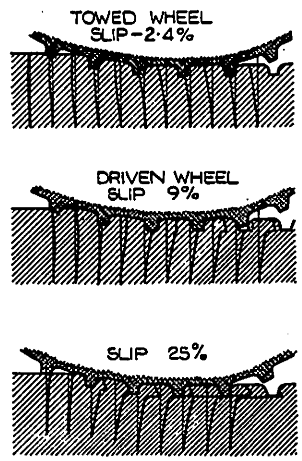

FIG. 4.
Söhne, " Grundlagen der Landtechnik," Heft 3/1952.

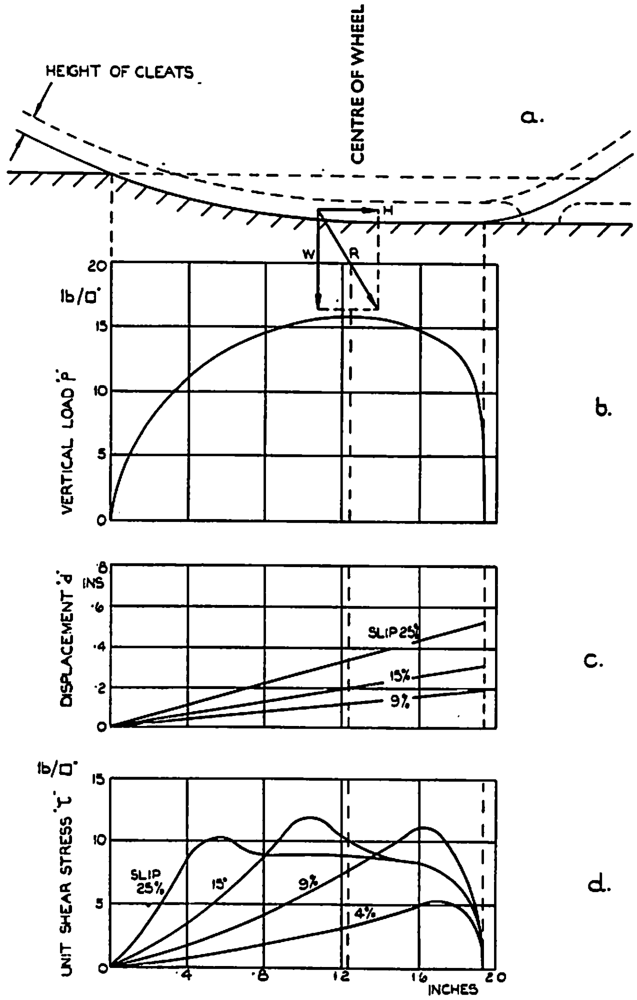

FIG. 5.
Söhne, " Grundlagen der Landtechnik," Heft 3/1952.

The transmission of horizontal forces between a conventional tyre and an average soil is well illustrated by Fig. 4 for one towed and two cases of driven wheels at 9% and 25% slip. The thicker lines show the displacement of chalk strands injected into the soil. The progressive displacement and deformation are clearly seen.

A more detailed sketch (Söhne) shows on Fig. 5a the location and direction of the main forces, and on Fig. 5b the distribution of the unit vertical loads along the contact area. Fig. 5c shows the gradual and uniform slip build-up from leading to trailing edge for three different total travel slips. Fig. 5d represents the distribution of unit shear stress along the contact area of the same wheel running at three total travel slip values. We can clearly see how the area under the curves increases at higher slips. These areas represent in each case the total gross thrust " H " ; hence also the increase of thrust with increased slip. The curves are arbitrarily established for a particular tyre load and soil conditions, and must be regarded as qualitative examples.

Fig. 5d gives also a good idea of the difficulty of calculating the thrust performance in view of the non-uniform distribution of the shear stress along the contact area. Bekker has introduced two additional new soil property coefficients k_1 and k_2 which enable such calculations to be made with a good degree of accuracy. These new coefficients can be calculated from curves taken during the soil shear tests, but the calculations are somewhat involved.

The friction between a smooth tyre and the ground surface is generally too small to exploit fully the soil shear strength available. Loose top soil, slippery vegetable matter and surface moisture make conditions even worse, and recourse must be made to cleats, grousers, etc., to cut through this low shear strength layer.

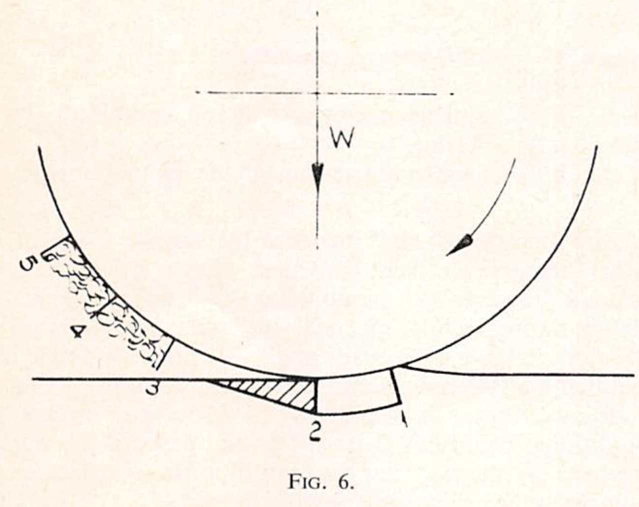

FIG. 6.

Fig. 6 shows diagrammatically a wheel fitted with grousers. On sandy, homogeneous soils the area between grousers 1 and 2 will shear on an arc connecting the tips of the grousers, thus providing very little advantage over a smooth wheel. Grouser 2 will make a small contribution, as an additional volume of soil will be subjected to shear, so long as the space between two adjacent grousers is not filled up with compacted soil as shown between grousers 3, 4 and 5. Practical maximum height of grouser, approximately $\frac{1}{4}$ pitch.

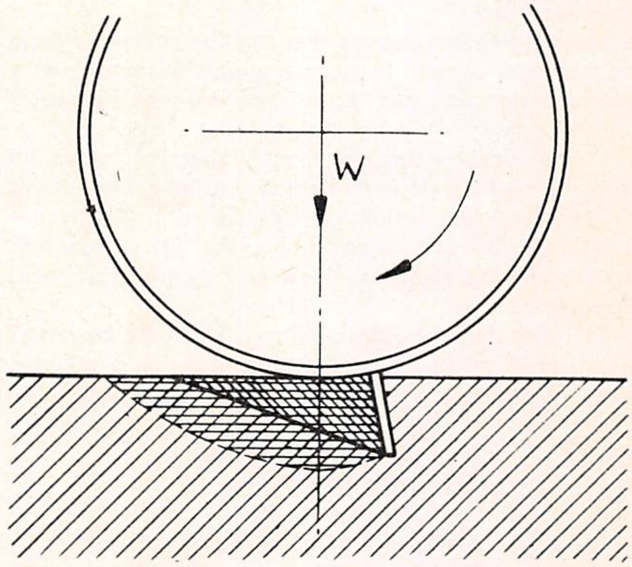

FIG. 7.

Fig. 7 shows the action of a single, rather high grouser in a homogeneous frictional soil. Theory and practice agree that only small tractive forces can be thus produced.

Unfortunately, the above considerations hold good whether the grousers are steel on steel wheels, steel on pneumatic tyres, or rubber bars on rubber tyres.

This somewhat disappointing statement, however, is only correct for homogeneous sandy soils. On more cohesive soils, of which clay is an extreme example, and also in other conditions, bars and grousers come into their own in the following way :

(*a*) On concrete surface covered with a film of water or a slippery film of any nature the rubber bars penetrate the film and obtain a good grip by direct contact with the firm surface.

(*b*) The same action occurs on hard (cohesive) soils covered with a slippery layer, as long as the latter is not too thick.

(*c*) There are many field conditions where firm, hard ground is covered by a loose layer of soil, sand or gravel. Rubber bars sweep this layer away and reach firm ground contact. The bars are, therefore, arranged under such angles as to push the loose soil sideways out of the tyre contact area. A somewhat similar action can be observed on turf or stubble. Unfortunately, a fair amount of wheel slip is required, so that traction efficiency is impaired.

(*d*) On cohesive soils, yet soft enough for the bars to penetrate, a sort of pinion and rack effect can be produced. The soil teeth are capable of taking shear forces larger than those which could be dealt with by pure frictional contact with a smooth tyre. Reversing the chevron tread on the tyres to point forward to the direction of travel may give a slight gain on some rare occasions, as long as the soil is not too cohesive.

(*e*) Strakes can penetrate deeper into the ground than rubber or steel bars. If they reach deep enough to meet a firm soil layer, traction can be greatly improved. Such devices, however, do a fair amount of digging, consuming power and fuel.

Summing up, we can say that traction is derived from the frictional contact between tyre and soil and from a sort of pinion and rack action between wheel grousers and soil.

A great deal of theoretical and laboratory work on grousers has been done by Bekker, but his main interest has been in track-laying vehicles and is probably not directly applicable to wheeled tractors. It is therefore not proposed to elaborate this aspect from a theoretical viewpoint.

To conclude this section, going back to the basic soil shear strength we can state that the maximum obtainable gross soil thrust can be expressed as :

$$H = AC + W \tan \phi + H'$$

where A = Tyre contact area.
C = Cohesive soil strength.
W = Vertical wheel load.
ϕ = Angle of internal soil friction.
H' = the additional force produced by cleats or grousers due to secondary effects like edge shear and drag, usually a small contribution of up to 10%.

Travel Resistance

The travel resistance can be split up into the following factors :

(*a*) Rolling resistance of the loaded tyre, as on concrete, caused by the incomplete recovery of the work performed on the leading edge in flattening it. This is due to the hysteresis of the tyre and structure.

(*b*) Compaction resistance caused by the work on soil necessary to compress it to the depth of the track imprint, usually denoted as sinkage.

(*c*) Bulldozing resistance caused by the work expended to dispose some soil upwards and sidewards around the tyre.

(*d*) Lateral drag of tyre caused by soil adherence (stickiness) and viscosity.

Surface Crossing

As long as the tyre can run on the ground surface with no, or very little sinkage, we shall have a condition defined by Bekker as " surface crossing " ; factors (*b*), (*c*) and (*d*) therefore do not apply.

The formula for the safe unit ground pressure in this condition is : $p_r = CN_c + \frac{1}{2}\gamma\, bN_\gamma$

where C = Cohesive soil strength.
N_c & N_γ = Constants depending on " ϕ " given by Terzaghi.
γ = Unit weight of soil.
b = Width of contact area (must be smaller than " *l* ").

As an example on a purely frictional soil ($C = 0$; $\phi = 30°$), with $\gamma = \cdot 06$ lb./cu. in., $p_r = \cdot 5 \times \cdot 06 \times 20 \times b = \cdot 6 \times b$, for a 13 in. wide tyre $p_r = \cdot 6 \times 13 = 7{\cdot}8$ lb./sq. in., but for a 15 in. tyre of same O.D., $p_r = \cdot 6 \times 15 = 9$ lb./sq. in.

Assuming that in a particular case we double the tyre width " b," we see that the safe unit ground pressure can be also doubled. Since the contact area is simultaneously doubled, the safe total load for surface crossing will be four times larger for the two times wider tyre. This condition is often met to its full extent in dry, sandy countries, but rather rarely in the U.K. Since, however, many agricultural soils contain a frictional element, some justification for wide tyres is not erroneous for many conditions. The travel resistance under surface crossing conditions is the absolute minimum attainable and is equal only to the rolling resistance of the tyre. It is, therefore, so important to realise that it may occur in some practical conditions.

Subsurface Crossing

Once the tyre has broken through the ground surface the soil-mechanics change and compaction resistance caused by sinkage " Z " becomes the principal contributing factor towards high travel resistance, bulldozing and drag making additional contributions to the primary evil. A tyre contact area which is long and narrow reduces the soil volume under compaction, and bulldozing even for the same sinkage is an obvious way.

Means to increase the length " *l* " of the contact area are neither easy nor cheap on wheeled tractors. Large-diameter wheels, multiple tracking wheels, low inflation pressures and super flexible tyres are the only remedies at our disposal.

A further argument supporting the benefit of larger " *l*/b " ratios (hence moderate width " b ") can be visualised by examining the reasonably accurate formula expressing sinkage under subsurface crossing conditions.

$$\text{Sinkage " Z "} = \left\{ \frac{p}{\frac{k_c}{b} + k_\phi} \right\}^{\frac{1}{n}}$$

where p = Unit ground pressure.
k_c, k_ϕ, n = Sinkage coefficients of soil, explained later.
b = Smaller dimension of the ground contact area $b \times l$.

Any increase of " b " increases the sinkage if all the other factors are kept constant. Even halving the ground pressure " p " by doubling " b " will produce a disappointing result on cohesive soils where k_c is relatively large and k_ϕ very small. It must be pointed out that if all the other conditions remain constant, travel resistance increases rapidly with increased sinkage. Additional confusion is caused to the practical tractor engineer by the fact that the transition from surface to subsurface crossing is not sharply defined.

Moving now towards a closer approach to the exact theory, Fig. 8 (Bekker) is presented showing a non-driven pneumatic tyre moving over soft ground. The first term of the associated equation gives the compaction resistance and the second term the rolling resistance of the tyre.

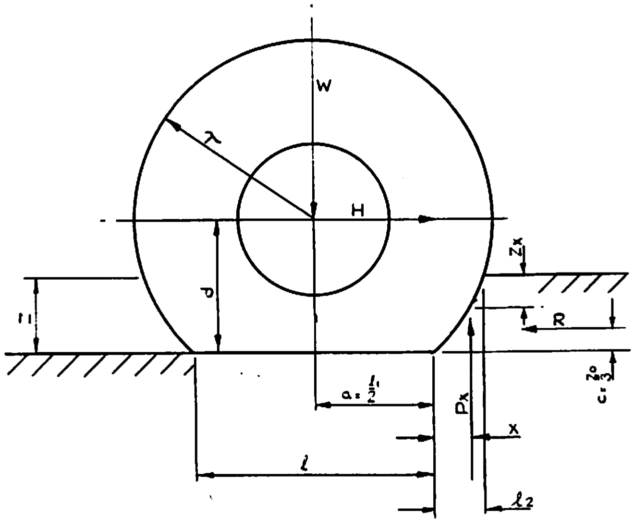

FIG. 8.
Pneumatic tyre moving over soft ground.
Bekker, " Off-the-Road Locomotion,"

Total travel resistance :

$$R = \frac{\left[b\,(p_i + p_c)\right]^{\frac{n+1}{n}}}{(k_c + b\,k_\phi)^{\frac{1}{n}}\,(n + 1)} + \frac{W_u}{p_i^a}$$

where b = Smaller dimension of the ground contact area b × *l*.

$p_i + p_c$ = Unit ground pressure exerted by tyre inflation and carcass stiffness.

k_c), k_ϕ), n) = Coefficients defining the relation of unit load to sinkage for a particular soil established by loading flat plates and measuring their sinkage in a special rig.

W = Vertical load applied to the tyre.

u), a) = Empirical coefficients of internal tyre resistance against rolling (different for every tyre and size of tyre), depending on number of plies, thickness of carcass, material and tread design. Established by tests on a hard surface.

The above equation is only valid if inflation pressure plus carcass stiffness are low enough to permit the tyre to develop a flat contact area as shown. Otherwise the tyre assumes a circular shape in both planes and becomes identical with a rigid wheel. Contact area is reduced, sinkage increases and the travel resistance can raise by up to 30%.

The formula is not easy to interpret at a glance and requires additional curves relating to the unit ground pressure ($p_i + p_c$) with the load supported by a *particular tyre*. Nevertheless, we can draw some qualitative conclusions aiming at reducing " R " when soil conditions (*i.e.*, k_c k_ϕ, and n) and vertical load W are kept constant :

(*a*) Width of tyre " b " should be kept low.

(*b*) Inflation pressure plus carcass stiffness should be as low as acceptable by tyre design and life requirements.

(*c*) United internal tyre resistance $\frac{u}{p_i{}^a}$, whilst not a big factor, should be as low as possible.

Cutting down " b " and increasing the ground pressure $p_i + p_c$ in the same proportion works the wrong way. Increasing " b " and reducing the ground pressure proportionally can be moderately effective if " k_ϕ " is large.

Reducing the unit ground pressure alone while keeping " b " constant is most effective, but not as easy as already mentioned previously. It means increasing " *l* " and/or running at a very low inflation pressure below, say, 8 lb./sq. in., which is around the presently accepted uncomfortable minimum. The formula discussed above applies fairly accurately to towed tyres only. For torque propelled tyres it is an approximation, the best so far known.

Drawbar Pull

The drawbar pull of a tractor is the difference between the gross soil thrust reaction H and the travel resistance R.

$$DP = H - R$$

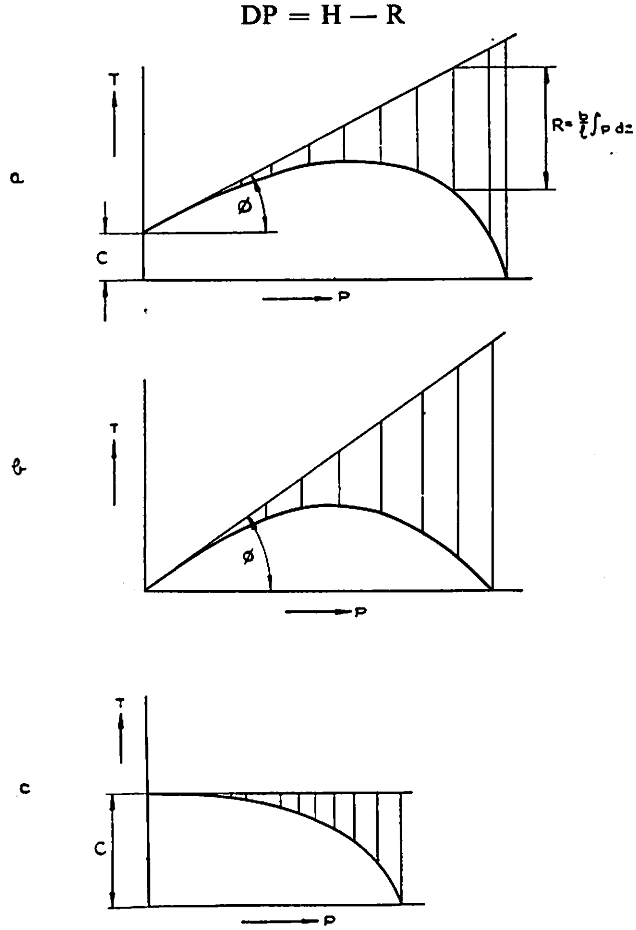

FIG. 9.
Trafficability curves for frictional and cohesive soils.
Bekker, " Off-the-Road Locomotion,"

The pursuit of the theories briefly sketched out permits us to establish curves for unit thrust " τ " as a function of unit ground pressure " p " for every imaginable variation of soil and tyre parameters. In the step by step process it is relatively easy to watch where a drift towards better or worse begins to occur. All examinations can be performed by calculation if a sufficient range of data on the parameters involved is available. Bekker shows samples of such curves (Fig. 9) and calls them " Trafficability Curves."

Curve. a. For an average soil like sandy loam.
b. For a purely frictional sand.
c. For a frictionless, purely cohesive wet clay.

Maximum thrust can be obtained only at a particular optimum ground pressure " p," but beyond this point

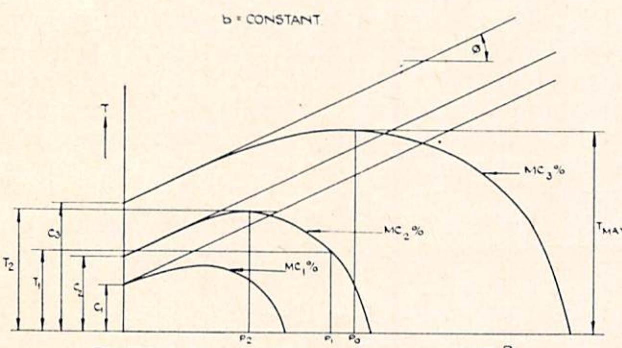

FIG. 10.
Trafficability curves for various moisture contents.
Bekker, " Off-the-Road Locomotion,"

drops quite rapidly to 0. Curves shown on Fig. 10 indicate clearly the thrust deterioration for the same soil if conditions change from dry (MC_3%) to humid and fully wet (MC_1%). These curves are excellent examples of what actually happens in field conditions. They go a long way towards settling the argument between high and low power to weight ratio tractors, showing that both have advantages and disadvantages, depending on soil conditions.

The distance between the shear strength line and the thrust curve represents the negative thrust required to overcome the compaction resistance. As unit ground pressure is increased, the magnitude of this negative thrust raises very rapidly. It must be noted that these curves give only approximate values. Ground pressure was assumed to be uniformly distributed ; no allowance for bulldozing and soil drag was made. The influence of slip on traction efficiency is not shown. In spite of the shortcomings, Bekker reports a fair agreement between such calculated curves and actual measurements made on full-size track-laying vehicles.

Pneumatic Tyres

After this introduction, we can examine the principal factors in pneumatic tyre design available to the engineer, and also at the same time try to make a number of practical comments :

1. *Diameter*

Large diameters are favourable in respect of traction, travel resistance and slip in Subsurface Crossing Conditions. A wheel of a very large diameter would actually be as good as a track. On harder ground the improvement is much less noticeable. There are, however, practical tractor design and cost limitations which bring us rapidly to a point of poor economic returns.

2. *Width of Section*

Increase of width is the easiest way to combat sinkage and most effective in Surface Crossing, as explained previously. It is, however, necessary to lower the inflation pressure, otherwise the gain—at least, with conventional tyre sections—will be disappointing. Tyre sidewall wrinkling is the danger associated with low pressures, so that the manufacturers' advice should be followed very strictly. It must be remembered that a given rim size will only permit a certain maximum section of tyre to be fitted. Beyond a critical limit, instability in the transverse direction and damage to sidewalls will occur.

Wide sections have not nearly the same beneficial effect in regard to slip and travel resistance as large diameters. However, a wider section reduces the unit pull load per 1 in. of length of bar and will contribute towards better bar life under adverse heavy pull conditions.

3. *Rim Size*

The modern tendency is rather towards wider rims, even for the same tyre sections as used heretofore. This is quite justified, as a wider rim increases slightly the section of the tyre. Furthermore, transverse stability is improved, and also if necessary a wider rim can take again a wider tyre section.

It must be mentioned that in our country tyre sections above 11 ins. are very unpopular, as there is no room in the furrow for anything wider. Ploughs wider than 12 in. furrow width are rarely used, due to the conditions and/or traditions prevailing.

4. *Shape of Section*

Present-day conventional tyres have an arcuate outer part of the section (disregarding the bars) approaching a semi-circle. There are good practical reasons for it, of which ease of self-cleaning is a major one. It can be assumed that a tyre with a more flat outer section will give better results on dry sand without the necessity of very low inflation pressures. I believe that such tyres are being produced already experimentally.

5. *Bars* (*Cleats*)

The variable design factors are :

Height.
Width.
Number (or pitch).
Angle.
Pattern.

From the viewpoint of traction alone, it would be best to use rather high and narrow bars to obtain deep penetration. The mechanical strength of rubber and the stiffness of the carcass are limiting factors leading all manufacturers to similar conclusions, resulting in an almost standardised bar section. Tyres with extra high bars are produced as special designs, and they give good results on wet, soft soils, but not on sand. On hard ground they give no advantage and wear out rapidly.

The pitch and angle are compromises dictated by the necessity to provide self-cleaning action and also reasonably smooth rolling on harder soils. Tyres used in this country are primarily designed for wet Spring and Autumn conditions, and it would seem that for dry countries finer pitches and small angles would be better.

In our country a pattern of the open-centre type has been standardised for field work to obtain good penetration and self-cleaning at a sacrifice of roadworthiness. An additional advantage of this design is a reduced transversal and circumferential stiffness favouring the accommodation of the tyre to the ground. In other conditions than ours, the open-centre type may not necessarily be the best.

6. *Tyre Carcass*

The ideal carcass would be very flexible, yet would provide a firm base for the bars, would be immune to flexing fatigue, immune to external damage and would not wrinkle even under highest driving torques, yet being able to withstand high internal pressures and high wheel loads. These requirements are contradictory and are met generally by a compromise of four or six plies, the choice depending on the tyre size and service loads. Low inflation pressure and large number of plies is an unfavourable combination.

7. *Inflation Pressures*

Lowering the inflation pressure increases the area of ground contact, as long as the ground surface can sustain a unit pressure (expressed in p.s.i.) approximating the internal tyre pressure plus carcass stiffness. We can also say : If the soil is softer than the tyre, reduced inflation pressure is of no advantage.

Wrinkling of the sidewalls is a deadly enemy of low inflation pressure, which, on the other hand, favours good tractive efficiency. It is, therefore, hoped that future technical developments will enable us to use lower inflation pressures without the associated wrinkling and adverse effects on tyre life.

8. *Tyre Loading*

The trend in tractor design leads all the time towards higher power to weight ratios. This is technically and commercially correct, and forces us into the necessity of increasing adhesion (chiefly at lower speeds) to be able to utilise the full available engine power for traction.

Tractor designers have been quite successful in the past in concentrating a larger proportion of all the vertical forces on the driving axle. These are derived from the tractor and mounted implement weights and also from downward vertical soil forces on the implement. There is naturally a practical limit to this procedure, and beyond this limit ballasting the rear axle becomes a necessity.

Any added ballast increases the tractive force available from the tyre, but also increases rolling resistance in all conditions and consumes additional power in uphill work. On all but very firm and level surfaces, ballasting above the critical amount will reduce the power available for the implement. Furthermore, running the tractor at, say, 50% of its maximum pull with ballast catering for 100% pull can be a great waste of fuel. It is, therefore, generally agreed that the ballasting weights should be easily removable.

9. *Water Ballast*

In spite of the tedious manipulation, this form of ballasting is very popular, chiefly due to the low cost. There is, in addition, one great technical advantage—namely, a reduction of sidewall wrinkling at 100% water fill. Water ballasted tyres can, therefore, be run without undue damage to the sidewalls at much lower inflation or rather internal pressures (where this is desirable).

Traction Augmenting Devices

We have already mentioned the main limitations of the pneumatic tyre, which can be summarised as follows :

Wet clay, certain kinds of vegetation, stubble, snow—all provide a lubrication layer between the ground and the tyre. If the rubber tyre bars cannot penetrate sufficiently to get hold of firm ground underneath, ballasting is of little use and even harmful under extreme conditions. Traction augmenting devices become, therefore, the only means of improvement.

Girdles

The cheapest and mildest device are the well-known tyre girdles. They cut through the slippery surface and obtain good grip from the firm soil underneath. Lugs can be fitted to the cross-bars, giving better penetration. The increase of rolling resistance is moderate, but proportional to the gain in traction. If not fitted with additional lugs, it is possible to negotiate hard patches or even to drive on the road at moderate speeds. On sandy soils the gain in performance is marginal, but on heavy and moist clays improvements in traction up to 50% can be expected. The penetration of the girdles is moderate, and if adequate traction grip cannot be obtained in, say, the first 2 in. of the ground, recourse must be taken to the next step.

Strakes

There are retractable and non-retractable varieties available. The first type is generally preferred, as they

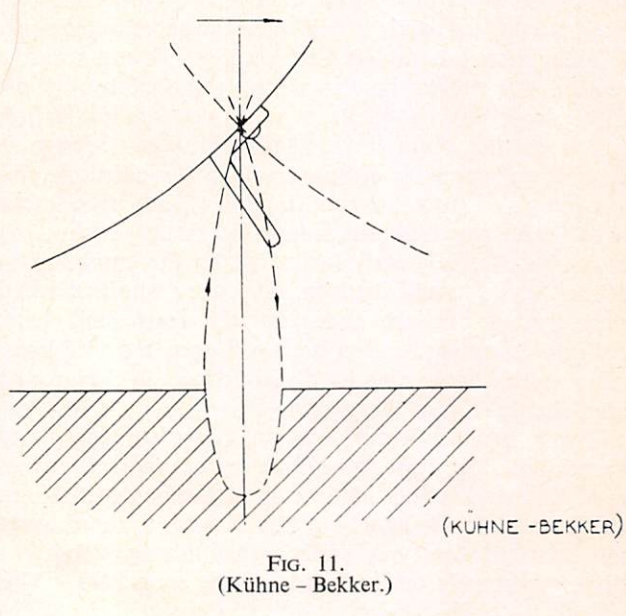

Fig. 11.
(Kühne – Bekker.)

can be stowed away for normal conditions and road work. Furthermore, most of them can be extended to variable depth, and this is quite an advantage.

It must be pointed out that the strakes disturb the soil, each of them digging into ground following the path of a truncated figure 8 (see Fig. 11). This consumes power and, therefore, they should not be made to protrude more than necessary for a given set of conditions.

On wet clay traction improvements up to 200% have been reported.

Cage Wheels

When tyre sinkage becomes the predominant factor, cage wheels enjoy an increasing popularity. They are fixed on the outside of the wheel, their diameter being smaller than the outside diameter of the tyre. The number of cage blades, their width, length and section vary according to the conditions of use and the experience and ideas of their designers. Excellent service is obtained in paddy fields and on moors, as these wheels reduce greatly the unit ground pressure and improve traction due to the large slices of soil submitted to shear. In a way, they are a further extension of the strake principle. A further advantage is that the tractor can move on hard ground with ease, as the cages are out of contact. Rolling resistance is high and they should, therefore, not be used where other aids suffice.

Tyre Tracks

This is a rather expensive attachment which can still be reasonably easily fitted to standard tractors. It is touching the borderline of the full track-laying vehicles. Their action is two-fold. First of all, a continuous mat consisting of two rubber bands and closely-spaced cross-bars is being laid for the rear track wheels. Secondly, the steel cross-bars, which can have various sections, put a large surface area of the soil into shear, thus augmenting the available traction. The best application for tyre tracks is snow, for which they were originally developed. The gradual compaction starting at the lightly-loaded jockey wheel is a correct action for snow. Wear of cross-bars and rubber bands is fairly good in those conditions.

When there is complete absence of stones and abrasive matter, the rubber bands can be replaced by chains. Life is surprisingly good, as snow has a certain lubrication action on the chain links. This Norwegian design is proving very popular in Scandinavia. Good results are also obtained from the rubber band type of tyre tracks in soft sand, rough terrain, woods and shrubs, as climbing over obstacles is greatly facilitated by the combination of mat laying, small load on the jockey wheel, reduced unit ground pressure and relatively sharp steel bars. An interesting application is on soft prepared seed beds, where tyre tracks leave hardly any trace on the ground after the passage of the tractor.

There are, however, several disadvantages and limitations. In most conditions, except snow, wear of cross-bars and rubber bands cannot be avoided. Sharp stones are a deadly enemy to this device. In hard usage the conventional tyres suffer some damage from the driving pommels on the inside of the cross-bars. This could be overcome by a special tread on the tyres, but such tyres would not do for general use. Steerability of the tractor is adversely affected and puts a limit on the amount of load which can be transferred to the jockey wheel as this load is taken off the front axle, impairing steering.

The tracks are too wide to be accommodated in the furrow whilst ploughing, and, furthermore, the tyre tracks are not capable of carrying large transverse forces, as the rear wheels tend to ride out of the tracks, unless special side lugs are provided. Lastly, these tracks are not suitable for speeds above 5 – 6 miles per hour, as wear becomes prohibitive.

Full Tracks

This adaptation is probably the limit of what can be done on the conventional agricultural tractor without going to a full-scale conversion into a proper track layer. The load on the jockey wheel is considerably increased by a suitable design and the unit ground pressure figure is quite favourable. Steering is effected by the use of the independent turning brakes, but would be quite inadequate for normal agricultural use.

Several units have been used with great success by Sir Vivian Fuchs' Antarctic Expedition, proving once more the amazing flexibility of modern agricultural tractors.

Tractive Efficiency

The power developed at the rear axle of a tractor cannot be transferred to the drawbar without losses. First of all, a part of it is used up to overcome the travel resistance of all wheels in ground contact. The main factors influencing this resistance have been discussed in this Paper.

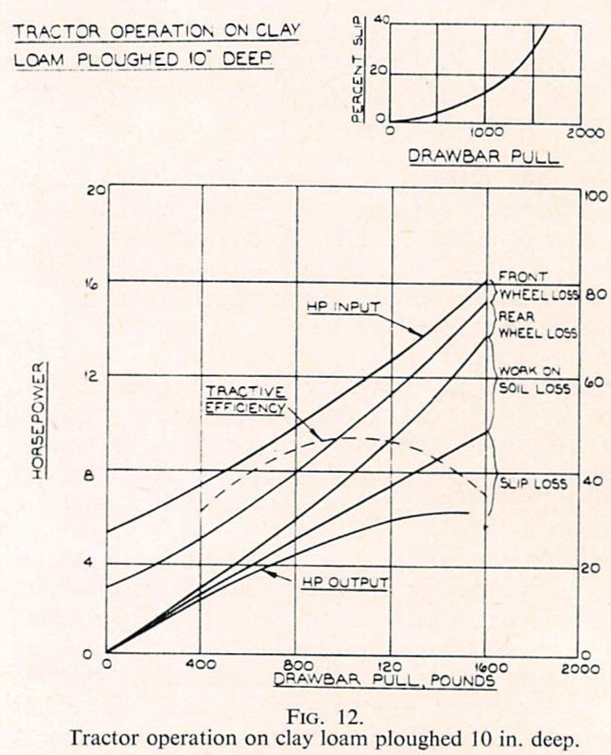

FIG. 12.
Tractor operation on clay loam ploughed 10 in. deep.

The second source of power loss is gradient resistance, favouring light tractors as long as they provide adequate adhesion.

The third cause is wheel slip. The percentage of wasted work is again directly proportional to the percentage of slip. Unfortunately, no tractive force can be developed by a wheel without some slip. In most field conditions the best efficiencies are obtained at 10 - 15% slip.

On anything but very hard and firm surfaces another factor becomes pre-eminent, and this is the work wasted in cutting, churning and displacing the soil. This loss is roughly proportional to the slip loss, and in soft ground conditions may become even higher than the latter. It is disappointing, but not surprising, that tractive efficiencies over 40% must be considered as reasonably satisfactory in actual field conditions. Fig. 12 is a good example of efficiency variations on one particular tractor. Fig. 13 presents typical efficiency curves for a few characteristic ground conditions.

The author feels that it is his duty to point out that he has not been privileged to conduct any basic or original work of his own. This Paper has been based mainly on publications by Bekker and also on some data by Söhne, Bailey, C. T. O'Harrow, Barger and others, and the author wishes to express his grateful acknowledgment of their contribution.

The aim has been to give tractor engineers a condensed insight into the present state of the theory and to give some practical advice as to its application.

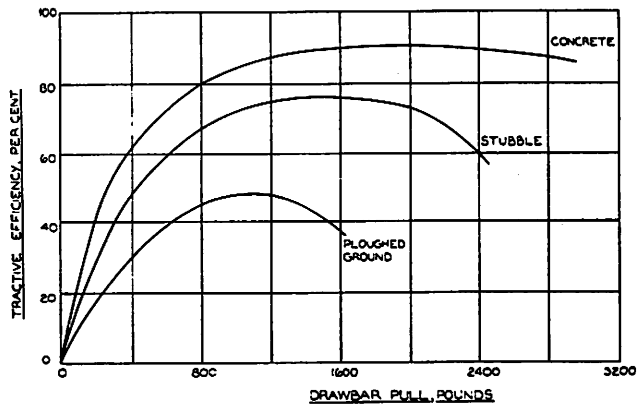

FIG. 13.

BRANCH PROGRAMMES (*continued*)

Committee :

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J. Weir, B.Sc. (Agric.), A.M.I.Agr.E., c/o North of Scotland Hydro-Electric Board, 16, Rothesay Terrace, Edinburgh, 3.

September 18*th*, 1963

AFTERNOON VISIT (3 o'clock) to the B.M.C. Factory, Bathgate, with an evening talk by one of the members of B.M.C. Staff.

October 17*th*, 1963

AFTERNOON VISIT (4 o'clock) to the Perth Marshalling Yard of British Railways. Visit to be followed by a talk in the evening by a B.R. official at the premises of Messrs. Caledonian Tractor and Equipment Co., Ltd., Lairwell, Perth, at 7.30 p.m.

November 4th, 6*th*, 7*th and* 13*th*, 1963

TALKS, " The N.I.A.E. Users' Testing Scheme " at four centres in Scotland, in conjunction with the N.F.U. —a series of talks :

November 4*th*, 1963

7.30 p.m., Laurencekirk—in the Masonic Hall. Speaker : W. J. West, B.A., Dip.Agric., M.I.Agr.E., Director, N.I.A.E., Scottish Station, Penicuik.

November 6*th*, 1963

7.30 p.m., Perth—at the Station Hotel. Speaker above.

November 7*th*, 1963

7.30 p.m., Edinburgh—in Lecture Room " E " of The Edinburgh School of Agriculture, West Mains Road. Speaker : D. I. McLaren, B.Sc., N.D.A., M.I.Agr.E., Head of Mechanisation Division of the N.I.A.E., Silsoe, Bedfordshire.

November 13*th*, 1963

7.30 p.m., Ayr—in Lecture Room No. 1 of the West of Scotland Agricultural College, Auchincruive. Speaker : W. J. West, B.A., Dip.Agric., M.I.Agr.E.

January 6*th and* 7*th*, 1964

Subject, " Mechanisation and Farm Productivity." Speaker : J. S. Nix, M.A., B.Sc. (Econ.), Farm Management Liaison Office, Wye College, University of London.

January 6*th*, 1964

7.30 p.m., Edinburgh—Meeting in The Edinburgh School of Agriculture, West Mains Road.

January 7*th*, 1964

7.30 p.m., Perth—Joint Meeting with Perth Agricultur
7.30 p.m., Perth—Joint Meeting with Perth Agricul- tural Discussion Society in The Ballroom, The Station Hotel.

January 14*th*, 1964

7.30 p.m., Aberdeen—Meeting in Lecture Theatre C.I. of the Robert Gordon's College, Schoolhill.
of the Robert Gordon's College, Schoolhill. Subject, " Accident Prevention on the Farm." Speaker : J. C. Brownlie, N.D.A., Chief Wages and Safety Inspector, The Department of Agriculture for Scotland.

AGRICULTURE IN PAPUA AND NEW GUINEA

by A. W. JEFFORD,* M.I.Agr.E.

Introduction

THE island of New Guinea, lying to the north of the Australian Continent, was first discovered in the 16th century by the Portuguese, and it was a Portuguese navigator who first named the island Papua (a Malayan word meaning "frizzy black hair"). In 1545, a Spanish navigator sailing along the east coast thought the people there resembled those on the African coast, and so called the island New Guinea. By the 17th century, the island was known to the Dutch, and in 1770 the Englishman, William Dampier, sailed around the island. In 1884, Holland annexed the western half of the island as Dutch New Guinea, and in the same year Great Britain, through Australia, proclaimed a protectorate over the southern shores and adjacent islands, and Germany annexed the remainder of the island. During the first World War, Australian troops occupied German New Guinea and established a military administration, this being replaced by the Australian civil administration in 1921, established under mandate from the League of Nations. At the end of the Second World War, the former German Mandated Territory was placed under the United Nations as a Trust Territory, with Australia as the administering authority.

The Land and the People

The island lies completely within the tropics, but climatic conditions range from the hot, moist coastal regions to the bitterly cold, lofty mountains, ranging up to 15,000 ft. in height. Rain forest covers the lower and middle slopes of these, but the bleak, higher levels are marked only by sparse and stunted vegetation. The rainfall varies from 60 to over 300 ins. yearly, and torrents pour down the mountain sides to water the productive areas at lower levels. There are many rivers, and of these the mighty Sepik flows over 700 miles to the North Coast, while the Fly River drains the southern slopes and flows some 900 miles and widens to a width of some 30 miles at the mouth. From the coast and extending up to the 7,000 ft. level are many fertile valleys and plains suitable for agricultural pursuits. The wild nature of the island is shared by the islands adjacent to it, and of these the most important are New Britain and New Ireland, both frequently shaken by earthquakes and volcanic eruptions.

The Territory of Papua and New Guinea comprises a total area of some 184,000 square miles ; of this, 151,000 square miles are under control of the Administration, and the remaining 27,000 square miles has been patrolled or is under partial influence of the Administration.

The people of the Territory vary widely in their colouring and other physical characteristics. Whilst comprising mainly Polynesian and Melanesian stock, the environment into which many of them have been forced by geographical or climatic conditions, and very often tribal warfare, has produced a multiplicity of types, ranging from the dwarf pygmies of the range forest to the tall Sepik hunters who live between the central ranges and the north coastal areas. In their primitive state, many of their customs are repugnant to humanity and they live in a state of warfare with their neighbours. Their lives are governed by fear and sorcery. They have no hereditary chiefs and no national unity.

One of the first steps to be taken was the exploration of the inland country by patrols, setting off on foot through the swamp and the mountains to find out what lay in and beyond them. These patrols usually consisted of one or two Australians accompanied by a party of native police and carriers. In 1927 such a party crossed the watershed between the Fly and Sepik rivers, and in 1934 the unknown area between the Strickland and Purari rivers was explored. In 1931 a patrol officer was clubbed to death in his camp at the headwaters of the Lakekamu river, and in 1939 a patrol left Mt. Hagen to explore the unknown Waghi Valley. Today, Goroka is recognised as one of the busiest airports in the Pacific area, yet twenty years ago it was classed as a restricted area inhabited by head-hunters.

From the foregoing description of the land and its people, it is quite apparent that the use of mechanised farming and industry offers problems seldom met elsewhere. Successful mechanisation is dependent upon efficient machines operated by qualified personnel and backed by an efficient service organisation. We, of course, have yet to achieve this happy state, and we must overcome many difficulties. It must be remembered that to all intents and purposes the native people live in the stone age, and the tools used by these people are made from stone or wood. The majority of village gardens are dug with the aid of digging sticks, and the transportation of produce to and from the gardens is achieved by carrying manually. In Papua the main language among the people is Motu, and in New Guinea a Pidgin English is used. Each tribe, however, both in Papua and New Guinea, has its own language, and there are also many variations in Pidgin due to the effects of the early white settlers, many of whom were of German stock. Thus in many of the highland regions, where only a short twenty years ago the people were untouched by civilisation, the only language they know is their own, and they now find

* Senior Mechanical Equipment Inspector, Department of Agriculture, Stock and Fisheries, Port Moresby, Papua.

they are required to learn Pidgin or English. It may be assumed that the people will overcome the language barrier with regard to their daily requirements, but it must be remembered that mechanisation demands a language of its own and that, unless the basic requirements are understood, machinery cannot be effectively maintained and operated.

All machinery is regarded by the natives as being alive or occupied by a spirit, and must evidently be given daily supplies of food and water. If the driver becomes ill, it may be that the spirit within the machine is evil and must either be cured or destroyed. This could be effected by administering a handful of soil with the engine oil.

The Department of Agriculture has within the Territory of Papua and New Guinea some 60 training centres and stations. From these the various phases of extension work, plant introduction and quarantine and animal husbandry are carried out. Each centre and station is equipped with machinery applicable to its function. We have field workshops at the major centres and machinery inspectors and mechanics who visit the centres as the occasion demands. It is one of the station managers' and visiting technicians' responsibilities to select and train indigenes in the operation of such agricultural machinery used in that area. This entails the problem of converting such technical jargon used by the Europeans into either the Papuan language or Pidgin English. This, in turn, must be converted by the trainee into his own " place talk " or local language. There are over 700 local languages in the Territory of Papua and New Guinea. This fact, together with the fact that natives are often transferred from the Papuan region to New Guinea and do not understand either the language or local customs and conditions, makes the job just so much more difficult. However, the standard of literacy and education is rapidly improving, and as the native people become more accustomed to seeing agricultural machinery in use the task is becoming easier. Whilst there is still some confusion regarding the usage of petrol, kerosine and dieseline, at least it is seldom confused with the use of water. It has been stated that the production of staple foodstuffs is usually closely interwoven with the social structure and religious beliefs and practices of the community concerned. Tastes, prejudices, fear of contamination of themselves and of their agricultural land, and the fear of relying upon unfamiliar crops are all difficulties in the way of any attempt to diversify and improve the efficiency of indigenous agriculture. Training programmes in new methods and the value of new and varied foods, however, help to hasten their adoption.

Departmental Activities

Into such a country and inhabited by what may be considered as among the most backward people in the civilised world, Australia is steadily pushing ahead with its programme of education in all its aspects. We, in the Department of Agriculture, have a stupendous task before us when one considers the agricultural conditions which exist in the more settled areas of the world. There is probably no other country where physical communications are more difficult. Sealed roads are practically non-existent and in the interior all cargo is air cargo ; the total extent of vehicular roads capable of carrying a 10-ton load would not exceed 6,000 miles.

Our function here is to develop and encourage the agricultural, livestock and fisheries industries within the Territory. Investigational and experimental work with Territory pastures and agricultural produce is undertaken by the Department. The results of this work are made available to both native and European agriculturalists through its extension services. The advancement of native agriculture has a high priority in government policy for the Territory. Of a total land area of about 184,000 square miles in the whole Territory, only about $2\frac{1}{2}\%$ is owned or occupied by the Administration or non-indigenous settlers. During 1959/60, native owners produced more than a quarter of the total production of copra and copra products, which was over 107,000 tons. It has been estimated that when all the cocoa trees planted in the Territory reach maturity about 25,000 tons of cocoa will be produced annually. Native coffee growers own about half of the 11,000 acres now planted. which is expected to produce over 3,500 tons annually.

The indigenous population figure at June, 1960, for the combined area of Papua and New Guinea is given as 1,880,326, and the non-indigenous population as 24,864. Of the indigenous population there are 41,612 paid persons in primary production. Included are 3,181 employed by the Government.

As at March, 1960, the number of cattle in the Territory is shown as 17,000. This includes both beef and dairy herds. There are also 1,400 horses and 4,232 pigs. Sheep have been the subject of experimentation, but are not adaptable to the Territory conditions. No figures are available regarding livestock owned by indigenes. Such livestock would comprise mainly pigs and poultry.

Rubber has been a major export for many years. The main plantings are in the foothills beyond Port Moresby. Planting is on the increase and established plantations producing high-quality rubber may be found in Papua and Bougainville.

At Garaina in the Morobe District the Department has a thriving tea plantation, with a factory capable of producing up to 100,000 lb. of dry tea per year. The plateau upon which the tea plantation is situated is roughly 2,000 ft. above sea level. It is, however, completely surrounded by a mountain range, the peaks of which tower above 11,000 ft. in height. This situation has the interesting factor of altering the climatic conditions on the plateau from what would be normally expected at 2,000 ft. to those experienced at a height of 4,000 to 5,000 ft. The only means of access to Garaina is by aircraft. At the coastal port of Lae may be found factories designed for the processing of such crops as peanuts, coffee and cocoa, and at Goroka, in the Central Highlands, is a factory designed to extract and can the juice of passion-fruit. Cash or subsistence crops grown by the natives include rice, yams, sweet potato, taro and tapioca, and the usual truck crops are corn, tomatoes, beans and cabbage.

Machinery Requirements

The importation of tractors for agricultural use in the Territory would not exceed 150 units annually. The majority of these units would be wheeled tractors fitted with three-point linkage equipment and in the 30/40 h.p. range. Such machines are available for purchase in the main Territory ports, which are Port Moresby, Lae and Rabaul. The range of choice, however, is restricted to three makes of tractor, and of these very little attention has been paid by the importing agents to ensure that the tractors are equipped to suit Territory conditions.

Usually the first attachment to be purchased would be a three-ton capacity, two-wheeled trailer fitted with a hydraulic tipping system. The transportation of stores and supplies is a major consideration in a country without properly formed roads. The trailer, as with all other machinery, must be of a design that may be easily dismantled for transportation by aircraft. For this reason, we accept the two-wheeled flat-top trailer with a hardwood floor and sides. Where facilities allow, the floor may be covered with mild steel plate, as we find that due to the climatic conditions the hardwood usually requires replacing in a very short time.

Cultivation equipment may be confined to the two or three-disc ploughs, tandem-disc harrows fitted with scalloped discs, terracer or trader blades for road maintenance, combine seed drills and rotary grass mowers. Such would be the field machinery requirements of the average Territory farm or plantation.

Such items as hammer mills, feed grinders and dairy machinery are not available locally and are usually ordered from Australia or overseas. The importation of such items is dependent upon the availability of cargo space in the very few cargo ships that call at the Territory ports. Items of processing machinery such as rubber rollers, coffee dryers and tea machinery would be the subject of a special order dealt with by the manufacturers of such items. The time element for delivery could be up to twelve months from placing the order.

One of the hardest-worked machines in the Territory is the rotary grass cutter or slasher. The grass growth is phenomenal and generally the native task force employed on stations is fully occupied in keeping the grass and undergrowth within reasonable bounds. In the first instance, such rotary cutters used on copra plantations are set at a height to cut the grass without damaging the coconuts which drop from the palms. As the areas are cleared of the latter growth, the cutter blade may then be lowered to cut closer to the ground in the areas from which the fallen nuts have been gathered. Another use for these machines is the control of pastures and crops grown for cattle feed. Of these cutters, the most popular is the trailed type units with a 60 in. cut. The trailed type are preferred to the three-point linkage units due to the uneven ground over which they are expected to work. It has been found necessary to thoroughly clean these units after work, as the sap and wet grass lodging in the underneath of the frame will cause the metal to corrode in a very short space of time.

Transportation Problems

On arrival of the machinery at the Territory port, the next step is arranging transportation of the goods to their destination. Lae is the only port with road access to the Highlands. Port Moresby and Rabaul have little or no roads outside the districts in which they are situated. Thus transportation is confined to the small coastal vessels of 50/100 tons capacity which trade among the islands and the aircraft which serve the island centres. Whatever method is used, it is often necessary to reduce the weight of the machine by stripping it down to such component parts as can be safely handled by the ship slings or the aircraft's loading capacity. A number of airfields are restricted in length, and on these the aircraft may be confined to a 600 lb. pay load. Cases have been known of completely dismantling a five-ton truck and cutting the chassis into several pieces with an oxy torch to enable the parts to be air-freighted into the Highlands. Following this procedure, the next step is to arrange for a mechanic to be flown in to assemble the machine. Such actions, of course, void all pre-delivery checks, 500-hour services and claims under warranty.

Again, the tractor you choose may have an entirely different engine to what you expected and should one be so unfortunate as to purchase a machine and then discover it is a model for which parts are not stocked, then your troubles are just beginning. It must also be remembered that by the time a tractor or any machine is delivered to this Territory the makers may have a new or modified model on the market. It is understood that tractors are designed to work under extremely diverse conditions, but I feel that from a practical Territory farming point of view the simplicity of maintenance and operation of agricultural tractors leaves much to be desired. Too much emphasis is placed upon the availability of maintenance and specialist repair facilities, which makes me wonder how good are the machines when placed in an under-developed country such as the Territory of Papua and New Guinea and left to the ingenuity of the owner or manager to maintain in a serviceable condition.

In our search for tractors and machinery suitable for use in the Territory by semi-skilled native operators, we have purchased many different makes and models. Of these, I have a vivid recollection of a unit advertised to contain only seven moving parts in the engine, in a power range from 17 h.p. to 60 h.p. and fitted with P.T.O. and three-point linkage. Starting was either electrical or by swinging the fly-wheel. The specifications appeared adequate and the advertising material quite convincing, so after due deliberation we purchased a machine and proceeded to put it to use. After the usual formalities of checking fuel and oil, the electric starter was engaged and the engine started. The instructions stated that a red warning light mounted on the panel would then be lighted. This was so, but was hardly discernible in the bright sunlight. To a native driver the light meant nothing, even if he saw it. The fact was the light signified that the crankshaft was turning in the correct rotation. Unfortunately, the only other method of ascertaining the rotation of the crankshaft was to engage a gear and drive away. I can assure you that when one engages a forward gear on a tractor and briskly drives off in reverse, the effect can be quite startling and very dangerous. The brochures also mentioned the sustained lugging power of the machine. This also is quite true. So much so that by releasing the clutch pedal in quite a normal manner the tractor would rear up and turn over.

Apart from what are regarded as normal engine or tractor replacement parts, very few machinery items are stocked by the local agents. Items such as bearings for ploughs and harrows would need to be flown from Australia, a distance of some 1,400 miles. With an air cargo rate of 4/4 per lb. from Sydney to Port Moresby, the cost of replacement parts could become very expensive. It may be observed at this juncture that with our native people in their primitive state, the abuse and maltreatment of machinery is the rule rather than the exception. It is evident that to maintain our machinery in a fit and proper condition the owner must be fully conversant with the operation and maintenance of machinery under his control and also strictly supervise even the most elementary stages of operation and maintenance requirements.

As I have previously mentioned, although Papua and New Guinea lie completely within the tropics, we do experience a diverse range of climatic conditions. Such conditions play havoc with electrical gear, fuel systems and clutch assemblies, and, in conjunction with the lack of service facilities and scarcity of replacement parts, make it imperative for the machinery owner to carefully estimate his maintenance requirements months in advance. It is, therefore, in my department our practice to purchase with each new machine a comprehensive range of parts which we hope will meet all eventualities. This department, of course, is more fortunate than the private settler, as we have a considerable amount of machinery on our books and we can afford to carry extensive stocks of parts and transfer such requirements from one station to another when the demand arises. The fording of rivers and the effects of the torrential rains experienced in this country have an extremely adverse effect upon the life of a tractor. Many of our rivers are extremely wide and fast-flowing. They are also subject to what we describe as " flash-flooding," during which the river level may rise many feet in just a few minutes. Vehicles attempting such crossings are fitted with upswept exhausts, and it is often necessary to remove the fan belts and endeavour to exclude the entry of water to the engine and electrical gear. After such river crossings, a complete oil change is often necessary. Travelling by road from Lae to the Highlands, eight such crossings are made, one of these being over a mile wide and taking up to an hour to negotiate. The prudent travellers on such trips travel in convoy wherever possible and carry sufficient supplies of food and fuel and oil to last three or four weeks. In the dry season the journey may be accomplished in two or three days.

Generally, our main sources of complaint regarding the maintenance of machinery may be confined to the bewildering complexities contained in many of the part books, the poor selection of tyre sizes fitted to the tractors, and the unhappy idea of two sizes in three-point linkage assemblies. I doubt whether the supply of a complete engine parts book will ever be solved, as the manufacturers appear to be bringing out modifications and engine changes faster than the books can be printed. As the country develops, it may be expected that service facilities will improve and it may be possible to obtain all our requirements off the shelf.

Conclusion

Because of a lack of suitable raw materials and lack of human skills, the economy of Papua and New Guinea must depend chiefly upon agriculture for development for some years to come. This will require continual expansion of markets for a comparatively narrow range of tropical products already in some cases in adequate or over-supply.

While there are many problems to be overcome in basic economic development and the expansion of communications, health and education I have confined my discourse to some of the minor complexities encountered in the development of agricultural mechanisation. These, I am sure, will eventually be overcome to the benefit of all concerned.

BRANCH PAPERS

Photostat copies of Papers delivered at Meetings of the Branches and not published in the Journal are now obtainable from the Assistant Secretary. The following, which were presented at a Short Paper Evening on March 4th, 1963, at the West Midlands Branch of the Institution, are currently available : " The Function of a Product Quality Department in the Mass Production of Agricultural Machinery," by B. Knight, Technical Investigation Engineer, Massey-Ferguson Tractors ; " The Use of Visual Materials in the Teaching of Agricultural Engineering," by M. G. Clough, M.Scl. A.M.I.Agr.E., Mid-Warwickshire College of Further Education ; " A Brief Survey of Current Trends in the Uses of Paper and Plastic Film in Agriculture," by J. C. Alcock, A.M.I.Agr.E., Bomford and Evershed, Ltd.

FOOD PREPARATION EQUIPMENT FOR FARM USE

by P. O. Wakeford,* A.M.I.E.E. A.M.I.Agr.E.

A Paper presented to the South-Western and Western Branches in March, 1963.

Summary

CHANGES in the pattern of British farming—in particular the trend towards intensification in the rearing of all farm livestock—are effecting a demand for more sophisticated equipment for the preparation of feeding stuffs on farms, and also for their mechanical handling and storage.

The Paper points out the need for adequate storage facilities for whole grain, including self-emptying reception hoppers, pre-cleaning plant and bulk storage, outlines the mechanical means available for moving grain from one to the other, and suggests that unless storage capacity is in excess of 500 tons the expense of self-emptying hoppered storage bins is not justified.

Storage of feed other than cereals is still most conveniently done in bags, but some farmers consider that pelleting of additives and their purchase in bulk is justified when new methods of mixing before grinding are to be used. Equipment for moving grain from store to grinding point is discussed and a specialised proportioning system for cereals and protein additive is described.

The basic requirements for hammermills and pelleters to be used on farms are given, and the point is made that high output is not a necessary criterion of satisfaction, but rather that consistent and continuous output matched to the farm food requirements is more important. It is therefore justifiable to use mills and pelleters of modest horse-power, 10 h.p. probably being the maximum ever needed from one machine for use on a farm.

Some of the problems arising from the nature of the materials to be dealt with by a hammermill are mentioned —in particular, " sticky " oats, straw in grain, and metal trash ; and solutions to these problems are suggested. Outputs in relation to horse-power of mills are tabulated.

Some account is given of the recent revival of interest in roller and plate mills, and a formula is given for estimating the amount of water which may need to be added to each ton of barley to reach the optimum moisture content of 18% required for rolling. Means of automating these mills so that grain and meal handling can be minimised are mentioned.

The merits of various types of farm mixer are discussed, and the relationship between gross capacity in cubic feet and tonnage mixed is suggested. The merits and possible limitations of a method of proportioning prior to milling are indicated.

Farm pelleting is briefly described, and a maintenance cost of 3/- to 5/- per ton is suggested.

Automatic control equipment for mills, mixers and conveyors is described, the need for attention in this connection to Farm Safety Regulations is mentioned, and the advisability of fitting an ammeter to mills and pelleters is emphasised. Various methods of stopping a hammermill when grain flow has finished are described, and a means of improving the grinding of grain when straw is present is indicated. A control method for stopping pelleting machines when material has ceased to flow is given.

Some suggestions for reducing man-handling of materials within the food preparation area are made, including a method for automatically weighing each ingredient into a mixer.

Finally, some interesting developments are described for moving prepared food from the food preparation area direct to where the animals feed.

Introduction

Changes in size of the pattern of British farming and the likelihood of these changes being accelerated are effecting a demand from farmers for more sophisticated equipment on farms, not only for the preparation of food for animals on their farms, but also for its mechanical handling.

Changing husbandry methods, particularly in the rearing of pigs and new milking methods, require that food should be consumed in a short time by animals, and have thus stimulated the development of " farm-sized " pelleting equipment. Intensive methods of rearing " baby " beef with mainly barley feeding have within the last year or so stimulated a demand for roller mills which is quite unprecedented.

It is assumed in this Paper that all three trends are giving a fillip to *farm* food preparation rather than to the purchase by farmers of ready-mixed rations, on the grounds that the economic benefit is likely to be of the order of £3 10s. per ton, even when all farm preparation costs are taken into account. It is probably still true to say that even when bulk delivery of ready-mixed food is practised the balance is still in favour of farm preparation. These points are arguable, but the purpose of this Paper is not primarily to enter into this argument, but to pose some of the problems that have been thrown up by the changes in farming methods outlined in regard to equipment at present available, and to suggest some of the ways in which the problems may be dealt with.

In order to do this, I propose to consider separately the various components involved in farm food preparation, which obviously include the actual food preparation equipment, but extend beyond it to storage and movement of the food.

* Agricultural Advisory Section, The Electricity Council.

These separate components are as follows :

1. Filling and storage facilities for grain and other feeding stuffs (mainly proteins and minerals).
2. Equipment for moving grain and feeding stuffs from store to food preparation area.
3. Food preparation equipment, including :
   (*a*) Hammermills.
   (*b*) Roller and plate mills.
   (*c*) Mixing equipment.
   (*d*) Pelleting equipment.
4. Automatic control equipment associated with the above.
5. Equipment for handling partly-prepared food within the food preparation area.
6. Equipment for moving prepared food from food preparation area to feeding areas.

This survey is not intended to be exhaustive, but in stating the problems associated with the above and possible solutions, I also propose to suggest annual throughputs necessary to justify automation of some of these components.

Filling and Storage Facilities for Grain and other Feeding Stuffs

In many cases storage facilities for grain will include drying facilities also. It is not intended to deal here with drying requirements, but it is worth pointing out that whether a farmer uses his own farm-grown grain or buys in bulk, essential features of the grain storage plant, apart from drying equipment, are :

1. A self-emptying concrete or steel-lined reception hopper.
2. A vertical conveying system feeding to—
3. A grain pre-cleaning plant and *via*—
4. Belt or chain and flight conveyors to—
5. Bulk storage.

In most cases, not less than 2 tons capacity (say, 120 cu.ft.) will be a minimum size for the reception hopper, while the vertical conveyor, which can be a bucket elevator or auger conveyor, should preferably have an output of not less than 20 tons per hour ($1\frac{1}{2}-3$ h.p.). If the output is only 10 tons per hour ($1-2$ h.p.), then to keep waiting time of lorries or tipping trailers at the reception hopper to a reasonable minimum, the capacity of the reception hopper would need to be increased to 5 tons (say, 300 cu.ft.). The grain pre-cleaner is important in connection with food preparation (*a*) in order to remove straw from recently combined grain, and (*b*) to remove trash from grain bought in from the docks. Straw in grain can restrict output from hammermills and trash in grain, particularly metal trash, can cause damage to their hammers and screens. While it is possible to purchase pre-cleaners which match the output of the elevator and so avoid bottlenecks at all times, most farmers are unwilling to pay £400 or so for a machine having an output of 20 tons per hour, and accept that pre-cleaning has to be done in slack periods at, say, 5 to 10 tons per hour before grain enters the hammermill. If this is necessary, then double-bucket elevators will usually be required, one set of buckets moving grain into the cleaner, and the other set moving grain after cleaning into a storage bin above the hammermill.

For horizontal conveying above grain bins, belt or chain and flight conveyors are now the most commonly used, and from the point of view of efficiency (*i.e.*, horsepower required in relation to output), and on grounds of cost, are to be preferred to pneumatic conveying.

The bulk storage method most likely to fit in with food preparation is storage of grain in bins, either flat-bottomed or self-emptying. Storage of grain on a floor, while cheaper and most suitable as a temporary measure during harvest, usually presents difficulties in requiring additional labour when the grain has to be moved to a different position on the same level for food preparation, but may have an application if milling and mixing equipment is on a lower floor, when arrangements for flow under gravity can be made.

Is the extra expense of completely hoppered self-emptying bins justified ? I would suggest that, except for storage capaciites of 500 tons or more, it is not ; there are available small augers which can be used to empty flat-bottomed bins almost completely as they travel at a low angle to the bin floor and sweep grain towards the outlet point.

The movement of feeding stuffs other than grain is still best done on farms in sacks or paper bags rather than in bulk. Chiefly this is so because weighed bags facilitate accurate compounding, so that measuring or weighing of cereals only need be involved on the farm. It may be mentioned, however, that one or two farmers who use recently introduced proportioning milling equipment have considered it worthwhile to buy the " additive " ration in pelleted form in bulk, and store this in a large hopper above the proportioning device. While there is an extra cost for pelleting the protein additive, this is offset by its purchase in bulk and the saving in paper bags.

It may be of interest to mention that a useful guide to the space needed and storage periods suggested for various feeding stuffs is given in the Electrical Development Association Handbook No. 5, " Milling and Mixing," on pages 61, 64 and 65, which is reproduced as Tables 70, 71 and 72 of the I.Agr.E. Year Book, 1963.

Equipment for Moving Grain and Feeding Stuffs from Store to Food Preparation Area

In the majority of farm installations this is still most conveniently done by moving the cereal portion of a ration from the grain storage by means of the conveying system into a buffer bin which is arranged above the hammer or roller mill. Such a bin can be conveniently calibrated by volume indication to give the right proportion of grain for each mix by means of lines marked on the bin. This usually involves manual levelling off.

One or two pioneer farmers in this country, on their own initiative, have developed more radical labour-saving devices for grain movement. One such is Mr. James Watson, of Muir of Pert Farms, Ltd., Tealing, near Dundee, who has developed a method of proportioning the flow of grain cereals and protein additive in the process of moving these from the storage point to the milling point. Two basic items of equipment are involved. One is a motor-driven chain and flight conveyor installed at ground level, and the other is a "flowmeter." This last consists of a fluted roller mounted in a small hopper below the outlet point of the cereal or protein holding bin, and rotated by means of a suitable-sized gear-wheel which is chain driven from another cog. This cog is on the same shaft as a sprocket which engages with the links of the chain and flight conveyor. Each "flute" of the fluted roller will carry a given amount of grain into the bottom channel of the conveyor, the actual amount carried at any time being varied by means of an adjustable slide above the roller. The position of the slide is adjusted according to the amount required of the particular cereal feeding into the "flowmeter."

As the chain travels at a constant speed, once each outlet slide has been correctly set along the chain length the flow at each of these points is constant and automatic proportioning of the various ingredients in their correct ratios is achieved.

In Mr. Watson's installation the protein additives are pre-mixed in a 10 cwt. mixer, from which they are conveyed by auger into a small "buffer" hopper with an outlet above the "protein" flowmeter.

All the materials for a particular mix are thus conveyed together *in the right proportions* by the chain and flight conveyor to a hopper at the end of its travel, from which they are elevated by auger to a hopper above the hammermill. Control equipment ensures that the whole plant shuts down if any one of the motors should fail.

Such a sophisticated system is, no doubt, justified when, as in this case, over 3,000 tons of feeding stuffs are processed each year. For the majority of farmers, however, who will probably handle quantities in the range of 50 to 250 tons per year, such expense is less easy to justify. While at the upper end of this range farmers can make use of a conveying system from store to food preparation area, and can have quite simple but accurate arrangements for gauging proportions by volume (instead of weight), at the lower end of the range (50–100 tons handled per year) storage in weighed sacks is a reasonable method to use ; and movement by sack barrow to grain hopper near the hammermill would still be an acceptable choice. The days are, however, fast approaching when this scale of activities will become uneconomic.

The correct position of the grain hopper for feeding the hammermill is of importance in ensuring easy working. Where single-level working with sacks from grain store to milling area is the only possible method, it is important to ensure that the entry to the grain bin is at low level so that lifting of sacks is kept to a minimum. It will often pay to sink the mill well below ground level and have the grain bin top finished 1 ft. to 1 ft. 6 in. above ground level. Where this is not possible, another alternative is to build a small calibrated grain bin at ground level and use an auger to feed grain into a small hopper above the mill. It will be necessary to provide an excess grain spillway back to the bin, as shown in Fig. 1, for this to be satisfactory.

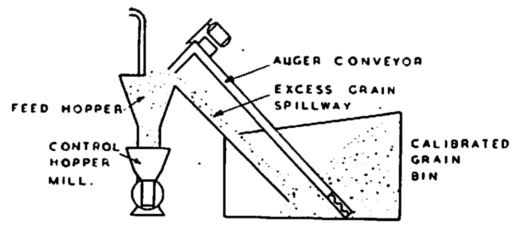

FIG. 1. CALIBRATED GRAIN BIN FILLED FROM GROUND LEVEL WITH AUGER FEED TO HAMMER MILL & EXCESS GRAIN SPILLWAY.

Where two-level working is possible, a satisfactory method of working is to feed grain from the grain store by conveyor into a calibrated bin built between first and ground floors. This allows grain to fall into the mill underneath, as shown in Fig. 2.

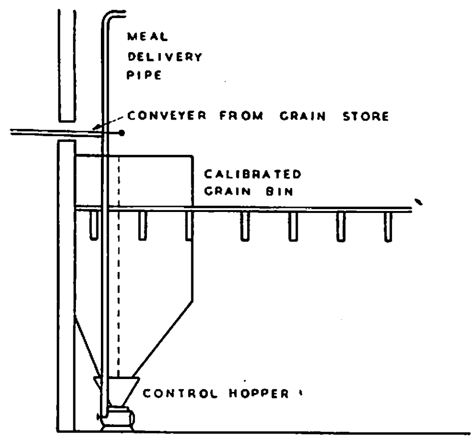

FIG. 2 CALIBRATED GRAIN BIN FEEDING HAMMER MILL IN TWO LEVEL WORKING FARM FOOD PREPARATION SYSTEM.

Food Preparation Equipment

Some general remarks may be made here. Because arrangements can quite simply be made for storage of prepared foods for short periods, in accordance with daily or weekly demands of the animals, there is no need for machinery for milling and pelleting to have high output as their main criterion of efficiency. What is more important is that equipment of modest horse-power requirement (rarely more than 10 h.p. for farm use) should be able to grind or pellet continuously for long periods without attention and should be able to be switched off automatically. An indication is given below of the type of milling, crushing and grinding, mixing and pelleting equipment which is available, with some of the problems which crop up in their use and suggestions for solving them.

Hammermills

The maintenance of consistent and continuous output from a hammermill is mainly a matter of design of the mill in order to cope with problems arising from the constituents of the material to be dealt with.

These problems are, firstly, those arising from the nature of the material itself—*e.g.*, "sticky oats"—and,

Table I
Outputs which should be obtainable when grinding cereals with mills up to 5 h.p. through different screens.

h.p. of Mill	*Output cwt./hr. when Grinding*								
	Wheat, Maize and Beans			*Barley*			*Oats*		
	Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine
1 ..	1·3	0·9	0·8	1·0	0·5	0·4	0·8	0·5	0·4
1½ ..	2·2	1·5	1·0	1·8	1·5	0·8	1·5	1·0	0·5
3 ..	5·0	3·5	2·2	5·0	2·5	1·5	4·5	2·0	1·0
5 ..	6·0	4·0	3·0	6·0	3·5	2·2	6·0	3·2	1·5

Coarse grinding is through approximately ¼ in. screen, Medium grinding is through approximately ⅛ in. screen, and Fine grinding is through approximately $\frac{1}{16}$ in. or $\frac{3}{32}$ in. screen—but average grist size varies also with design of hammers.

Coarse is usually suitable for cattle, Medium is usually suitable for pigs, and Medium or Fine is usually suitable for poultry.

secondly, those caused by " foreign " materials in the cereal—*e.g.*, straw or metal trash. In regard to the first point, it has been found in practice that where such varieties of oats as S147, S172 and SUN II have to be ground, mills in which the grinding and blowing chambers are virtually in one maintain output consistently for long periods better than mills in which these chambers are separate. The latter type of design will maintain its output satisfactorily when grinding cereals other than " sticky oats."

In regard to the second point, " foreign " material such as straw is dealt with better by the " single chamber " mill, although if straw lengths are as long as 6 in. these can sometimes reduce output to zero in the small mill up to 5 h.p. The best solution is to clean the grain first ; where this is not done, one solution which works quite well is offered by one mill maker. The problem to be overcome is to provide sufficient air flow at the entrance to the milling chamber to " stroke " in straw as it appears at this point. The mechanism referred to is based on the fact that when output falls because of straw in grain the current in the mill motor falls also. A more detailed description of the device is given in the section on control equipment.

Metal " trash " in grain can cause damage to hammers and screens if drawn into the grinding chamber. Cleaning such contaminated grain before allowing it into mill feed hoppers is undoubtedly the best solution, but if this is not done 95% protection is afforded in many small mills by the design of the mill feed hopper. In most of these a combination of gravity and air suction is necessary to get grain into the grinding chamber, so that where a " trap " is provided adjacent to the suction chute, heavier metal materials will nearly always fall to the bottom of the trap and not be drawn in. These traps must, however, be cleaned out periodically. In some (usually larger horse-power) mills gravity alone is used to get grain into the mill. In such cases a magnetic trap is essential, but it should be noted that it will only retain magnetic materials, and affords no protection against damage by non-magnetic metals or stones.

In deciding the optimum size of mill to use for a particular installation, it is important to assess the probable maximum hours of use in any one week. I would suggest that the aim should be to provide a mill which will not normally be required to work for more than 50 hours in any one week.

By assessing the weekly amounts of material used by the farmer and working out grinding times from Table I above, the most suitable size of mill can be chosen.

Roller and Plate Mills

A few years ago it would have been apparently true to say that both these types of mill were on their way out, but within the last two years or so they have had a significant return to favour. This is so, I believe, partly because farmers dislike the amount of dust resulting from hammermilling, and partly because of the increase in " barley fed " beef rearing which calls for the use of crushed barley. Both roller and plate mills produce a less dusty product than hammermills, but I notice that Calverley suggests in a Paper* presented at last year's Annual General Meeting that with roller milling the optimum moisture content of the grain is about 18%, and that at lower values than this kernels tend to shatter and give a product more like coarse milling.

If grain is stored in bulk at m% moisture content, the amount of water (W gallons) to be added per ton of grain stored to bring it up to the optimum value of 18% may be calculated from the formula $W = (49{\cdot}2 - 2{\cdot}73m)$ gallons of water per ton of grain. For example, for each ton of barley stored at 15% m.c. initially, 8·2 gallons would be needed to bring the bulk up to the optimum moisture content of 18% m.c. for rolling barley.

In order that the whole mass of material stored at a particular moisture content should be brought up to a higher one, it is essential to add the required amount of water 24 to 36 hours before the grain is ground.

At least two manufacturers now offer crushing mills with automatic feed and pneumatic delivery of crushed meal into bins. A recent design includes a *separate* motor-driven fan, the sole purpose of which is to blow crushed material into a bin. Pneumatic delivery, while convenient, increases the dust problem even with crushed material, and all receiving bins must be fitted either with cyclones or filter bags to release the air from the system. Acceptance into a bin immediately underneath a crushing

* D. J. B. Calverley, " Milling and Mixing on the Farm," *I.Agr.E. Journal*, Vol. 18, No. 2, May, 1962.

mill is therefore probably the best practice, but adequate storage capacity can only be arranged if the mill is on an upper floor and the store underneath.

Perhaps the most satisfactory system is that in which a roller and a plate grinding mill are combined above a "conveyor"-type mixer, which acts as a most suitable store for crushed or "plate" ground material. Outputs of grain through a crushing mill depend to a considerable extent on the setting of the rollers, but are usually comparable with the figures given for coarse grinding in Table I earlier.

Mixers

Most farm mixers installed in recent years have been of the vertical bottom-filling, bottom-emptying type. In these the ingredients are lifted by auger from a low-level hopper and circulated within the machine, the material being delivered at sacking-off height after mixing. Such machines are often linked with a mill for automatic delivery of the cereal proportion of a mix, and can be arranged to deliver meal direct into a farm pelleter or into the boot of a bucket elevator for storage or subsequent further treatment.

Capacities of mixers should always be quoted in cu.ft., as well as in cwts. (or tons), for since meal mixture densities vary, quotation by weight can be misleading. As a rough indication, however, the relation between *gross* capacity and weights capable of being mixed is as shown in Table II.

Table II
Approximate Relationship between Capacity (cu.ft.) and Weight of Mixtures held in Vertical Mixers.

Gross capacity (cu.ft.)	24	44	66	90
Wt. of "average" mix held (cwt.)	5	10	15	20

There is very little demand for a 5 cwt. machine, the most popular sizes being the other three. It is worth noting that, provided stocks of ingredients are readily available, a 1-ton machine should be able to mix that quantity in 40 minutes, and the material sacked off and stacked. In a 7-hour day, therefore, it is perfectly reasonable to expect 10 tons to be mixed. Thus 50 tons per week could easily be dealt with by this size of machine —equivalent to an annual output of 2,500 tons. The smaller mixers will provide proportionally smaller quantities.

Other types of mixer are the horizontal and conveyor-type machines. The horizontal mixer, capacity for capacity, is twice to three times the price of the vertical machine, but will carry out wet mixes as well as dry ; this, however, will require double the horse-power of a dry mix of similar capacity.

The conveyor-type mixer is an excellent machine in which mixing is achieved by means of moving slats between a pair of endless chains fitted within a trapezoidal-shaped container. It costs rather less than the vertical machine, has similar horse-power requirements, but has the considerable advantage that its motor can be arranged to drive a plate and roller mill mounted over the mixer at the same time as the mixing mechanism is operating.

Now that the National Institute of Agricultural Engineering has carried out tests on a number of makes of mixer, it is possible to obtain a comparative assessment of mixing efficiency from the results of the trials, which in particular relate to times to fill and to empty, and assess the ability of mixers to mix trace elements as compared with mixing these by hand when turning once, twice, and three times. In some cases, machines have been shown to produce a result better than three times hand turning in three minutes mixing time.

As has already been indicated, ingredients can be mixed prior to milling. Apart from the non-proprietary equipment operated by Mr. Watson in Perthshire, an English manufacturer has imported a "Mix-Mill" system from the United States. In this system, up to four ingredients are fed from hoppers into a "proportioning" unit above a hammermill. The proportioning unit consists of four small augers, the rate of movement of each of which can be separately controlled by means of a notched dial. The settings of these dials can be adjusted to give the correct proportions of each of the four ingredients which is required in the final mix as each passes into the hammermill. After grinding, the mixed meal drops from the mill into a horizontal auger and then through an inclined auger into a sacking-off spout or storage bin.

A possible limitation of this unit is that it is essential that all the ingredients should be free flowing in the hoppers above the proportioning unit. If they are not, then accurate metering of the flow ceases and the plant shuts down automatically. A further slight disadvantage is that where more than four ingredients have to be proportioned, pre-mixing these ingredients in their correct proportions is necessary prior to their flow through a channel of the proportioning device.

Pelleting Equipment

Three pelleters specifically for farm use have been developed in the United Kingdom. In two of these, pellets are extruded through a rotating perforated die of heavy construction by two fluted rollers mounted in contact with the inner periphery of the die. Dies can be changed to provide different sizes of pellet. Maintenance cost is fairly heavy, since wear of the rollers and the dies takes place and replacement cost is of the order of £60 – £65. A conservative estimate of maintenance cost is 5/- per ton processed, although with certain types of less abrasive mixtures it may be as low as 3/- per ton.

The third pelleter developed works on a piston principle. It is understood that satisfactory large pellets ($\frac{3}{8}$ in. or more dia.) can be made with this machine, but that small ($\frac{1}{8}$ in.) pellets still present something of a problem which has not finally been solved. The horse-power requirement for this machine is rather less than that of the other two.

Outputs from these machines are of the order of 1 cwt. per hour per horse-power for large $\frac{3}{8}$ in. pellets (often called "cubes"), and about $\frac{1}{2}$ cwt. per hour per horse-power for small $\frac{1}{8}$ in. pellets ; 5 h.p. or $7\frac{1}{2}$ h.p. motors are usually fitted.

Automatic Control Equipment for Food Preparation Machinery on the Farm

The amount of automatic control equipment which can be justified on farms is roughly proportional to the amount of food dealt with annually. This being so, it may be useful to suggest what are the minimum requirements for any installation, and to indicate the scope for more elaborate means of control on the larger installation. I propose to interpret " control equipment " in a fairly wide sense to include such ancillaries as ammeters, which can be an essential part of a control system.

What, then, may be regarded as the minimum control equipment for milling, mixing, pelleting and conveying ? The first thing to be pointed out is that every motor-driven appliance above ½ h.p. must have a push-button or hand-operated starter to control the operation of the motor. While this may seem obvious, it is surprising how frequently one finds a mixing machine, for example, which is started and stopped by a double or triple-pole switch-fuse. This does not give adequate protection to the motor should it be overloaded, and if the motor stopped because of an overload blowing a fuse in a switch-fuse, the blowing of one fuse would not necessarily have isolated the motor from the supply, whereas with a starter the thermal overload protection will isolate the motor completely. Furthermore, if a supply interruption should occur, when supply is restored again, if only a switch-fuse is controlling the mixer motor, the machine might be overloaded or someone could be working on the machine and serious injury could result. With a starter, however, which is fitted with a " no-volt " coil, the supply cannot be re-connected to the machine motor until the starter itself is operated.

These safety points are, of course, covered in the Farm Safety Regulations now in force, but are worth emphasising. It is worth pointing out also that these regulations require a device on the machine itself by means of which the operator can quickly stop it, if the main control point is some distance from the machine.

An ammeter should always be regarded as a necessary item of control equipment for mills and pelleters, as it gives a visual indication of serious overloading, so that remedial measures can be taken quickly.

Other control equipment which may be regarded as essential includes devices for stopping a hammermill or pelleter automatically when a batch of material has been processed. In the case of the hammermill, a " flap control " switch may be used, whereby the movement of a counterweighted metal flap upwards when grain ceases to flow over it operates a micro-switch and stops the motor. The diaphragm switch carries out a similar function, but relies on the cessation of pressure on a rubber diaphragm built into the control hopper above the mill to release the pressure on a micro-switch and switch off the motor. A further method is the " no-load " control switch. In this a magnetic circuit is maintained while the motor current is above a pre-set value—its *no*-load current. When the current falls to this value due to a cessation of grinding, the magnetic circuit is broken ; this causes a mercury switch in series with the starter coil to open mechanically, and thus the motor is switched off.

A further item of control equipment for the hammermill which may be desirable, although not essential, is the means of improving air flow to cope with straw in the mill control hopper referred to briefly above. This operates as follows : A solenoid is mounted alongside the entrance to the mill control hopper and carries the main current of the mill motor. A plunger inside the solenoid core moves up or down according to the strength of the mill motor current. When output and therefore motor current falls, the plunger, which is connected by levers to a hinged flap fitted at a position over which grain is sucked into the mill, moves upwards and causes the flap to fall, so that an increased air flow occurs at this point which helps to stroke straw into the mill. This device, known as a " master control " unit, I have found to be effective in operation.

The control of flow of meal into pelleters is more complex, since not only does the flow of meal have to be stopped, but any liquid additive (water or molasses) has to be stopped also. Furthermore, it is usually necessary to allow a time delay after the last of the meal has entered the pelleter for the material still in the body of the machine to be pelleted. One arrangement for providing the necessary control is to fit a " probe " in the meal flow. While meal flows, the probe is held " off-centre " and keeps a micro-switch in the " open " position. When the flow stops, the probe returns to a central position and the micro-switch is closed. This operation starts a timing motor fitted in a control box rotating slowly, and after one minute a cam brings a second micro-switch into action, energising the coil of a solenoid valve, which shuts off the water supply to the meal. After a further two minutes a second micro-switch is operated by a second cam, and a coil in the control box is thus energised, which attracts a " keeper," opening the starter circuit of the pelleter motor and stopping the machine. At the same time, the supply to the timer motor is cut off and the control equipment is then ready for the next cycle of operations.

Using the same principle, sequential control of a number of machines can be achieved, but it is necessary for manufacturers or suppliers to provide adequate information as to their purpose, preferably with a wiring diagram. Quite often an electrician is faced with a mass of equipment without instructions and has to work out the sequences and operations for himself. Time and expense would certainly be saved if this is provided by the suppliers *before* the wiring is commenced.

Equipment for Handling Partly-Prepared Food within the Food Preparation Area

After grinding cereals, they have generally to be moved to a mixing machine. After mixing they have to be moved to a pelleting machine. Sometimes, as with the combined milling and mixing units, the two machines can be coupled up and meal blown pneumatically from mill to mixer. Sometimes a mixer can be direct-coupled to a pelleter, but, of course, has to be kept running while pelleting is proceeding.

On occasions, however, a farmer may wish to grind more cereal than the content of one ration, and therefore needs to divert ground meal into a holding bin temporarily. Most will then man-haul the meal by sack into the mixer as appropriate, weighing *en route*, but if operations are on a large enough scale—say, 500 tons or more per year—there is a good case for automating this operation. One device has very recently been put on the market. The mixer itself is mounted on a weighing scale having movable markers with contacts connected to the starters of motors controlling augers for emptying the contents of discharge bins direct into the mixer. As material from one bin reaches the appropriate weight, the marker switches its motor off and, in addition, switches the next bin's motor on, until the second bin's quota is provided. The writer has not yet seen this in operation, but for large-scale farm mixing this appears to offer very substantial savings in labour cost.

Material to be pelleted after mixing may cause a bottleneck in the mixing process on a large-output plant if the mixer feeds direct into a pelleter. A combination of bucket elevator with meal bin above the pelleter will offset this disadvantage, but can be quite expensive, possibly increasing the cost of installing pelleting equipment by 50% or more of the basic cost of the pelleting machinery. Wherever possible, therefore, there is every reason to recommend moving pellets (or meal where appropriate) direct to where the animals eat it without intervening storage, and this brings us to the last section of this Paper.

Equipment for Moving Prepared Food from Food Preparation Areas to Feeding Areas

Wherever possible, food preparation areas should be located close to the area of maximum use of food on the farm. Where this is done it is then possible to arrange inexpensively for movement of food to where the animals actually feed. A number of different solutions are available, and it may be convenient to consider some of these in relation to the type of animals being fed.

Dairy Cow Feeding

Where cows are being milked in a parlour (herringbone, chute or abreast), it is possible to use simple metering hoppers by means of which measured quantities, usually of cubes, but sometimes of meal, can be accurately fed to individual animals. These hoppers need to be replenished at intervals. If meal is being fed, this can often be done by using an auger with the receiving end in a hopper in the food store, and the delivery end feeding into a travelling calibrated hopper in the milking parlour. However, if cubes are fed, particularly if they are farm-produced cubes, an auger delivery system is not so suitable because cubes are likely to be broken up in the auger. It is then advisable to use a bucket elevator to remove material from the cuber as it is cubed, transferring the cubes at a higher level to a belt conveyor above the milking parlour. Cubes may then be diverted in turn to the measuring hopper or hoppers, and automatic flow switch control can be used to switch off the cuber, bucket elevator and belt conveyor in that order.

Pig Feeding

Proprietary automatic feeding systems are already in use which can be adjusted to ration meal from a storage hopper in the pig house. It is also possible now to use a combination of horizontal and vertical augers to move meal direct from a mill to a number of pig houses where the meal can be delivered direct to self-feed hoppers. Switches actuated by the pressure of the meal are being used to shut down the mill motor once a series of the hoppers have been filled.

Another very simple system of distributing meal in pig houses has been devised by Mr. J. Watson, mentioned earlier. Meal is transferred by auger to small holding hoppers mounted at one end of the pig house. An endless " binder " chain running the full length of the house and back at a higher level is fitted near the top of storage feed hoppers at the end of each pig sty. The movement of the chain simply sweeps material into the first hopper, which is about 5 ft. long. When this is full the overflow is swept into the next hopper and so on. This system works very well indeed.

Poultry Feeding

A number of automatic poultry feeders have been in use for some time in this country, used mainly in broiler houses. An interesting adaptation of one of these systems has recently been made for automatic feeding of poultry in batteries. In this method meal is pushed through a 1½ in. tube by a continuous system of links and discs. The meal is distributed in front of the birds by having openings along the tube where it passes along the cages.

Conclusion

A Paper of this nature can only cover superficially the many current developments aimed at reducing the need for human handling of feeding stuffs for animals. It is probably true to say that few further developments are likely in farm food preparation machinery, but that the scope for future progress in the mechanised handling of the food once prepared is still very large. This Paper will have served its purpose if it has drawn attention to some of the ways in which these developments may take place.

THE PAINTING OF AGRICULTURAL EQUIPMENT

by R. A. FIDLER *

A Paper presented to the West Midlands Branch in September, 1962.

Introduction

IT has been said that more farm machinery rusts out than wears out, and certainly the conditions of use and storage demand much from a paint film, whose thickness is measured in thousandths of an inch. Let us, therefore, first take a closer look at the actual make-up of paint before we go on to the application side and painting methods used.

Composition of Paint

Paint is comprised of the pigment, the medium and the volatile. Broadly speaking, the pigment gives the colour required, the medium holds the pigment together in the form of a film, while the volatile enables it to be applied to a surface and then disappears as the film dries. The medium and volatile, or thinner, are usually incorporated together to form the vehicle, which carries the pigment, or without the pigment exists as a transparent coating, which is termed varnish or clear lacquer.

The pigments can range in price from a few coppers to many shillings per pound, and are grouped as follows :

Natural.
Manufactured.
Dyestuffs.
Whites.
Blacks.
Extenders.

An example of the first group is English Red Oxide, and whilst it is cheap, with good weathering properties, it does not have the same brightness or fine texture as the manufactured red oxide, which is prepared by heating ferrous sulphate. Whereas the natural and manufactured pigments are all metallic compounds, the dyestuffs are organic compounds—*i.e.*, compounds of carbon, derived principally from coal tar, and it is this latter group that is used extensively in the manufacture of red enamels that are so well known as the " house colours " of tractor manufacturers.

The whites have been kept separate from the first two groups, as there is no naturally occurring white pigment suitable for an enamel finish. While one visualises white cliffs, etc., the chalk of which they are composed would not make a good white paint. It would appear very dirty and yellowish if placed alongside a paint made with titanium dioxide, which is a manufactured pigment having a pure white colour and great opacity. At the other end of the scale a black would appear not to present any problems, but these pigments, manufactured by burning various substances, such as oil, bones, vegetable matter and natural gases, can vary just as much in their undertones so that by comparison one will appear to be more grey, blue or brown than black. The last group, the extenders, are mainly earth pigments with no tintorial strength, so that when added to a medium they are practically transparent. They are frequently used to cheapen a paint, but find no place in enamels where the maximum opacity is required. Certain of these extenders do, however, have useful properties. Thus they can be employed to reduce settling and to give build, particularly in undercoats.

The medium, or varnish, part of the paint is its fundamental basis, vast in its possibilities and in the different types that are available. It is the main factor in determining whether the paint will perform satisfactorily or whether it will break down prematurely. It governs the viscosity, the flow, the odour, whether the paint is suitable for brushing, spraying or dipping. In the same way that an engineer will select a certain metal and a certain gauge, and even a certain type of nut for a specific job, so the paint manufacturer must choose exactly the right medium to suit each particular industrial product and requirement.

The medium for a paint may be :

Oil.
Oil varnish.
Spirit varnish.
Cellulose lacquer.
Synthetic varnish.

Linseed oil is an example of the first group where the pigment and oil are mixed together to give a paint of the kind that was commonly used years ago. Such a paint would be quite unsuitable for modern industrial usage owing to its very slow drying and its softness. By incorporating a resin, a much faster and drying harder product is obtained. There are many different resins from natural sources, the most widely used being resin which is obtained from the pine tree. Fossil resins are obtained from the fossilised resinous remains of trees that existed many years ago. Some resins are obtained from living trees in much the same way as rubber latex. This kind is used in spirit varnishes simply by dissolving in a suitable solvent such as methylated spirits. Another resin—namely, Shellac—is unique in that it derives from an insect. It forms the basis of a wide range of spirit varnishes. The cellulose lacquers are made from nitro cellulose, which is normally produced by the action of nitric and sulphuric acids on cotton cellulose in the form of cellulose linters. Nitro cellulose is extremely in-

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flammable and is therefore never dried, but is sold damped down with an alcohol.

The synthetic resins form the most important group and are the materials that are mainly used in the formulation of paints for the agricultural equipment industry. The term synthetic has often been misapplied and presents in the minds of people the idea of substitute. Synthetic is derived from the word "synthesis," meaning a building up or putting together, and when applied to resins is based on the fact that such resinous materials, possessing complicated structures, are formed or built up from non-resinous materials of relatively simple structure. The synthetic resins are therefore produced initially in a pilot plant on a laboratory scale and then in bulk in the works. In this group are the alkyds, the melamines, the phenolics, the acrylics, the vinyls, the epoxies and many others, all with their own particular advantages and disadvantages, so that there are many permutations possible in paint manufacture to ensure that the right material is selected.

The volatile or solvent part of the paint needs little explanation, except that such materials are usually obtained from the petroleum industry or coal tar distillation. The paint will dry either by evaporation of the solvent as with a spirit varnish, by oxidation as with an alkyd air drying paint, or by polymerisation, which is induced by stoving or the addition of a catalyst.

Methods of Application

Having selected the right paint, we are now confronted with almost twenty methods of applying the paint. The choice of the most suitable method is dependent upon its efficiency and the size and number of articles to be painted. Paint application falls readily into two main groups :

(*a*) Those where the paint is atomised and the atomised particles are transferred to the surface to be coated, where the fluid film reforms.

(*b*) Those where the coating remains in a completely fluid state during application.

Methods in Group (*a*) include :

- Hand spraying.
- Automatic spraying.
- Hot spraying.
- Electrostatic spraying.
- Airless hot and cold spraying.
- Aerosol spraying.

Methods in Group (*b*) include :

- Brushing.
- Dipping—controlled dipping,
  - dipping with centrifuging,
  - dipping with electrostatic,
  - detearing.
- Flow coating.
- Tumbling.
- Roller coating.
- Flushing.
- Curtain coating.

The hand spray gun is a well-known example of the first group where compressed air is used to atomise the paint. As a method of application, it is extremely versatile, permitting the spraying of articles of intricate shape and also rapid change from one colour to another. On the other hand, the efficiency of the method can be low, due to paint wastage by overspray. In practice, therefore, the amount of dried paint actually deposited on a particular surface can be much less than the theoretical mileage.

As already explained, the major function of the solvent constituent in a paint is to permit application, and after this it evaporates. The hot spraying techniques, therefore, use heat to promote the flow of the paint and thus reduce the solvent content to a minimum. The airless method of application operates by subjecting the paint to pressures ranging from 600–1,500 lb. per sq. in. and then releasing through a small orifice. Electrostatic application is also used in the industry, the principle being that a positive charge of 100,000 volts is imparted to atomised paint, which is attracted to the article to be painted by making it at negative potential. Of the methods in Group (*b*), dipping is used extensively, as it is quick in operation and can give complete paint coverage to an article with a minimum of waste, as surplus paint drains back into the dip tank. Finally, the humble brush and roller play their parts, not only in repainting by the farmer or dealer, but also on the factory production line. Having chosen our paint, therefore, and method of application, let us consider the processes to be found in the typical factory producing agricultural equipment.

Production Line Painting

Pre-treatment

Wherever the factory and whatever the process, one necessity is for adequate cleaning and pre-treatment prior to painting. Without this, no paint stands a fair chance of meeting the difficult conditions that lie ahead, and whilst cleaning is a time-consuming and expensive process, paint failure in service can be even more costly. Castings for engines are dipped in a crankcase sealer either at the foundry or on arrival at the factory, and this not only protects but seals in small residues that might otherwise be dislodged later and introduced into the oil system. After machining, castings are cleaned to remove residual oils in a washing machine incorporating an alkali cleaner operating at 180° F. The crankcase sealer is usually a cellulose-based paint that will air dry very quickly, give complete coverage on castings, and also stand the hot cleaning solutions.

Small sheet-metal articles and other castings can be cleaned in alkali cleaners and phosphated to give maximum corrosion prevention and paint adhesion, or with larger equipment, where it is impossible to pass through cleaning tanks, solvent wiping by hand is employed, but great care must be taken for this to be effective. Unless the solvent is periodically replaced, excessive contamination will occur and future use will merely spread a thin film of oil over steel which may have been cleaner before the so-called cleaning operation took place.

Priming

Whether small or large, all articles should be primed as soon as possible after cleaning, and this is essential with many parts that are hidden on assembly and thus escape final painting. Small items can be painted by dipping in primer, and then hooked to mono-rail or flight bar conveyors to make the process as automatic as possible. Individual jigging of many of the very small items can be avoided by loading these articles into wire baskets that are then immersed in the paint, withdrawn and passed through stoving ovens.

An ideal arrangement is where workpieces can be cleaned, pre-treated and dried on a continuous production system, then proceed directly to an adjacent plant where they are dipped in primer and stoved. The red oxide primer used gives maximum corrosion protection and is a suitable colour for over-painting with red enamel at a later stage. Articles which are too large to enter the dip tanks or on which further assembly or welding would damage the paintwork can be sprayed with the same primer in a spray booth using any of the atomising methods of application and the paint then air dried, force dried or stoved.

Despite the desire to restrict the types of paint in use to the smallest possible number, special problems demand special paints, and an etch primer is sometimes used on combine harvesters. The front part of the combine harvester is constructed of cold-rolled steel sheet, and due to its size it can only be hand cleaned and painted with air drying or force dry paints. Satisfactory adhesion of paint films is difficult to obtain with this grade of steel under such conditions, but the use of an etch primer applied to a thickness of 0·00025 in. overcomes this problem. The etch primer can be applied outside the main spray booth and has sufficient time in which to air dry before application of the enamel. The painting of fertiliser hoppers also presents special problems, as the chemical fertilisers are strong enough to remove paints of the convential type and primers based on epoxy resin are recommended.

Enamelling

" House colours " identify the source of the product, and it is, therefore, an essential feature that the colour remains unchanged during service. Exposure to all the elements is a tough assignment for any paint, and a red poses peculiar problems. For this reason, specifications often stipulate the use of helio red, as the pigment and skilled formulation is required to produce an enamel that incorporates the maximum amount of pigment to give a paint of good opacity, and at the same time be of the required gloss. The medium for such paint is a mixture of alkyd and other resins suitably modified to give the desired application properties and drying characteristics.

Tractors are produced on a production line basis, and automatic methods of painting are employed as much as possible. Bonnets, hoods, etc., can be finished using electrostatic spraying, and enamels must be suitable for this method of application. The tractor chassis and engine assembly can, however, be sprayed by hand, using cold, hot or cold and hot airless application and then followed by a stoving operation. After leaving the oven, the tractor chassis and engine assembly proceed along the production line, where other previously painted parts —*i.e.*, bonnet, hood, etc.—are added, and the fully assembled tractor is driven off at the other end of the line for test and despatch.

Combine harvesters present many problems on account of their size and shape, and there are restrictions in the stoving temperatures that can be employed for the curing of the paint to avoid damage to tyres, battery, etc. For these reasons, an enamel that would force dry at 180° F. was developed that could be applied by airless spray. This plant not only reduces the amount of over-spray, but facilitates high speeds of application. The harvester can, therefore, be driven into the spray booth and, after painting, into the oven, where the paint is dried for 30 minutes. One hour after exit from the oven, transfers can be affixed, and in a very short space of time the harvesters can be driven to the outside storage sites. It is not unusual, therefore, for equipment to be exposed to the elements an hour after drying of the paint, and as the demand for some of the equipment is seasonal, it may stand outside for anything up to six months before delivery, but the customer, however, expects it to look the same as the day it was first painted.

Equipment in Service

At last our piece of agricultural equipment has been manufactured, painted and despatched to the user. Let us look at some of the conditions the paint film will have to meet and let me remind you once more that each coat of paint will probably be no thicker than 0·001 in. Firstly, the machine will be walked upon, scratched by boots, flying stones, etc. Fuel oils will be spilt on the paint and it will be subjected to rain, sunshine, heat, cold and, in fact, almost every kind of climatic conditions. The paint maker has to take all these factors into consideration when formulating the paint and devise laboratory tests that will reproduce these conditions. Painted panels will, therefore, be bumped, scratched, exposed to ultra-violet light and immersed in water, but despite all these tests useful and necessary as they are, only actual service conditions will prove the suitability of the paint.

Under such conditions, the paint will in due course lose its original gloss and perpaps colour, whilst in some areas the paint may be removed allowing the metal surface to rust. Repainting at some stage will be necessary, and as with factory painting the first step is adequate preparation. Grease and dirt should be removed by use of steam cleaning, or washing down with a solvent such as white spirit, taking care to ensure that electrical parts, rubber hoses, etc., are suitably protected. Rust patches should be cleaned by the use of emery-cloth or wire wool, whilst old paintwork should be flatted by the use of 280 or 320 grade wet and dry paper. The entire implement should then be wiped dry with clean, non-fluffy rag. Bare metal spots should be touched in with primer either by brush or spray and allowed sufficient drying before application of the undercoat. The undercoat should preferably be allowed to dry

Concluded on page 108

1963 EXAMINATION RESULTS

NATIONAL DIPLOMA IN AGRICULTURAL ENGINEERING

Pass with Second Class Honours	*Centre of Training*
Baird, G. J., Comrie, Perthshire	Private Study.
Bailey, A. L., Evesham, Worcs.	Essex Institute of Agriculture.
Christie, A. C., Saltcoats, Ayrshire	West of Scotland Agricultural College.
Edmunds, J. R., Farnham, Surrey	Essex Institute of Agriculture.
* Goodfellow R. E., Crosskeys, Mon.	Essex Institute of Agriculture.
McLean, K. A., Basingstoke, Hants.	Essex Institute of Agriculture.
†* Tullberg, J. N., Brighton	West of Scotland Agricultural College.
† Willcocks, T. J., Folkestone, Kent	West of Scotland Agricultural College.
Pass	
Aboaba, F. O., Nigeria	University of Newcastle.
* Brunner, S. G., Poulton-le-Fylde, Lancs.	Essex Institute of Agriculture.
Ellison, C. W., Newbury, Berks.	Essex Institute of Agriculture.
Gray, E. A., Chester-le-Street, Co. Durham	West of Scotland Agricultural College.
Halford, D. G., Bury St. Edmunds	Essex Institute of Agriculture.
† Hancock, P. N., Hunningham, nr. Leamington Spa	West of Scotland Agricultural College.
Hutton, G. J., Newbury, Berks.	Essex Institute of Agriculture.
† Mead, D. A. C., Crowborough, Sussex	West of Scotland Agricultural College.
† Moon, A. G., Bath, Somerset	West of Scotland Agricultural College.
Oliphant, A. J., Cupar, Fife	Essex Institute of Agriculture.
Sartain, J. C. Aylesbury, Bucks.	Private Study.
Smith, F. S., Coventry	Essex Institute of Agriculture.
‡ Starling, R. P., Ely, Cambs.	Essex Institute of Agriculture.
† Warren, J. D., Bridport, Dorset	West of Scotland Agricultural College.
Watson, P. S., Thame, Oxon.	Essex Institute of Agriculture.
** Whittall, R. W., Fort Victoria, S. Rhodesia	West of Scotland Agricultural College.

* Winner of 1962/63 Shell-Mex & B.P. Bursary.
† Intermediate N.D.Agr.E. gained at N.W. Wiltshire Area College of Further Education.
‡ Winner of 1962/63 Dunlop Scholarship.
** Intermediate N.D.Agr.E. gained at College of Aeronautical & Automobile Engineering, Chelsea.

GRADUATE MEMBERSHIP EXAMINATION

Pass	*Centre of Training*
Addae, Y. N., Ghana	Chelsea College of Aeronautical & Autobmoile Engineering.
Agyare-Aboagye, E., Ghana	Chelsea College.
Ankrah, B. O., Ghana	Chelsea College.
Davies, R. K., Pewsey, Wiltshire	Lackham School of Agriculture.
Dines, R. D., Basingstoke, Hants.	Lackham School of Agriculture.
Hadley, M. J., Hedge End, Hants.	Rycotewood College.
Holloway, B. D., Wimborne, Dorset	Lackham School of Agriculture
Khoo, T. C., Malaya	Chelsea College.
Knight, T. J. M., Wincanton, Somerset	Chelsea College.
Leaf, R. J., Dorset	Rycotewood College.
Massey-Cross, A., France	Lackham School of Agriculture.
Mensah, J. A., Ghana	Chelsea College.
Mitchell, D. G., Birmingham	Lackham School of Agriculture.
Okai-Koi, N. K., Ghana	Chelsea College.
Osmond, C. R., Netherwallop, Hants.	Lackham School of Agriculture.
Punia, H. S., India	Chelsea College.
Quansah, E. K., Ghana	Chelsea College.
Randall, R. J., Pewsey, Wiltshire	Lackham School of Agriculture.
Roberts, P. D., Evesham, Worcestershire	Rycotewood College.
Statham, R. N., S.Africa	Chelsea College.
Townsend, A. C. C., S.Africa	Chelsea College.
Troughton, T. J., London	Chelsea College.
Webb, B., Lechlade, Gloucestershire	Rycotewood College.
Wilford, C. D., Maidstone, Kent	Lackham School of Agriculture.
de Zoysa, D. J. W. G., Singapore	Chelsea College.

1963 EXAMINATION RESULTS

INSTITUTION EXAMINATION

Pass

BEADLE, E. F., Lincoln .. .. Private Study.
FARROW, B. T., Camborne, Cornwall .. .. .. Private Study.
LAMIN, W. H., Arnold, Notts. .. .. Private Study.
LOW, J. P., Truro, Cornwall .. .. Private Study.
MOTT, J. B., Norfolk .. .. Private Study.
SHIPPEN, J. M., Boston, Lincs. .. .. Private Study.

N.B.—The Institution Examination will completely replace the Graduate Membership Examination from 1964 onwards.

OBITUARY

It is with great regret that Council records the death of Mr. Joseph Rogers Knox, M.I.Mech.E., M.I.Agr.E., who died on October 20th, 1963, at the age of 72. Mr. Knox was a Founder Director of Gascoignes (Reading), Ltd., and will be sadly missed by all members of the Gascoigne Group, his many friends in the agricultural industry and those with whom he worked so closely on many of Reading's educational and charitable activities.

RELIEF OF INCOME TAX ON SUBSCRIPTIONS

THE ATTENTION of new members is drawn to the following copy of a letter from the Senior Principal Inspector of Taxes. It will be seen that those to whom it applies should ask for Form P358 from their Inspector of Taxes and complete and return it to him as soon as possible.

Ref. : C1/SUB/182. *October 8th*, 1958.

DEAR SIR,

I have to inform you that the Commissioners of Inland Revenue have approved THE INSTITUTION OF AGRICULTURAL ENGINEERS for the purposes of Section 16, Finance Act, 1958, and that the whole of the annual subscription paid by a member who qualifies for relief under that Section will be allowable as a deduction from his emoluments assessable to income tax under Schedule E. If any material relevant change in the circumstances of the Society should occur in the future, you are requested to notify this office.

I should be glad if you would inform your members as soon as possible of the approval of the Society. The circumstances and manner in which they may make claims to income tax relief are described in the following paragraphs, the substance of which you may care to pass on to your members.

Commencing with the year to 5th April, 1959, a member who is an office holder or employee is entitled to a deduction from the amount of his emoluments assessable to income tax under Schedule E of the whole of his annual subscription to the Society, *provided that*—

(*a*) the subscription is defrayed out of the emoluments of the office or employment, and
(*b*) the activities of the Society so far as they are directed to all or any of the following objects :
  (i) the advancement or spreading of knowledge (whether generally or among persons belonging to the same or similar professions or occupying the same or similar positions) ;
  (ii) the maintenance or improvement of standards of conduct and competence among members of any profession ;
  (iii) the indemnification or protection of members of any profession against claims in respect of liabilities incurred by them in the exercise of their profession ;

are relevant to the office or employment—that is to say, the performance of the duties of the office or employment is directly affected by the knowledge concerned or involves the exercise of the profession concerned.

A member of the Society who is entitled to the relief should apply to his tax office as soon as possible after 31st October, 1958, for Form P358 on which to make a claim for adjustment of his pay as you earn coding.

Yours faithfully, (Signed) T. DUNSMORE, *Senior Principal Inspector of Taxes.*

The Secretary, Institution of Agricultural Engineers.

ELECTIONS AND TRANSFERS

Approved by Council at the Meeting on June 27th, 1963

ELECTIONS

ASSOCIATE MEMBERS		Bolton, C. D. N.	Middlesex
		Christian, R. J.	Essex
COMPANION		Dadd, C. V. T.	London
ASSOCIATES		Baird, W.	Perth
		Carby-Hall, J. R.	Yorkshire
		Cooper, A. F.	London
		Jarvis, L. H.	London
		King, P. H. T.	Norfolk
		Riley, K. J.	Somerset
	Overseas	Hill, G.	Uganda
		Kidd, A. R.	Kenya
		Pazery, F.	West Africa
GRADUATES		Wise, B. W. F.	Wilts.
	Overseas	Joseph, C. C.	Ceylon
		Scholtz, D. C.	South Africa
STUDENTS		Hancock, P. N.	Warwickshire
		Lane, A. R.	Warwickshire
	Overseas	Clemitson, M. J.	South Africa

TRANSFERS

FROM ASSOCIATE MEMBER TO MEMBER	Overseas	Spear, G. B. H.	Iran
FROM GRADUATE TO ASSOCIATE MEMBERS		Cross, D. W.	Salop
		Cunney, M. B.	Ireland
		Smith, P. H. S.	Warwickshire
		Smith, W.	Cumberland

The Painting of Agricultural Equipment—*continued from page* 105

overnight before application of the enamel coat, as whilst there may be a surface hardness, a paint film takes some little while to achieve complete hardness through the film. All painting should be carried out in as dust-free an atmosphere as possible and preferably in a heated area. Painting that is carried out under conditions of high humidity can produce paint films exhibiting "blooming," low in gloss or with slower drying characteristics. As one of the highest charges in re-painting will be for labour, it pays to use a paint of good quality, and remember it can often be said that the quicker the dry so the quicker the life of a paint film, so do not attempt to speed up the process at the expense of durability.

Conclusion

By now you will have began to appreciate the many factors affecting the appearance of a piece of agricultural equipment. Linked with the vast resources of this industry you have those of the paint manufacturers, who are constantly striving to provide new and better finishes, and the "know how" of equipment manufacturers offering many methods of paint application. From the time these resources are first brought together until the tractor or combine harvester leaves the production line with its gleaming coat of paint, many processes have taken place—cleaning, pre-treatment, priming, enamelling and stoving operations. For the best results, therefore, it is essential that each of these processes is carried out as efficiently and economically as possible so that we can compete in the markets of the world and be proud of the title "Made in England."

Let electricity increase your farming profits

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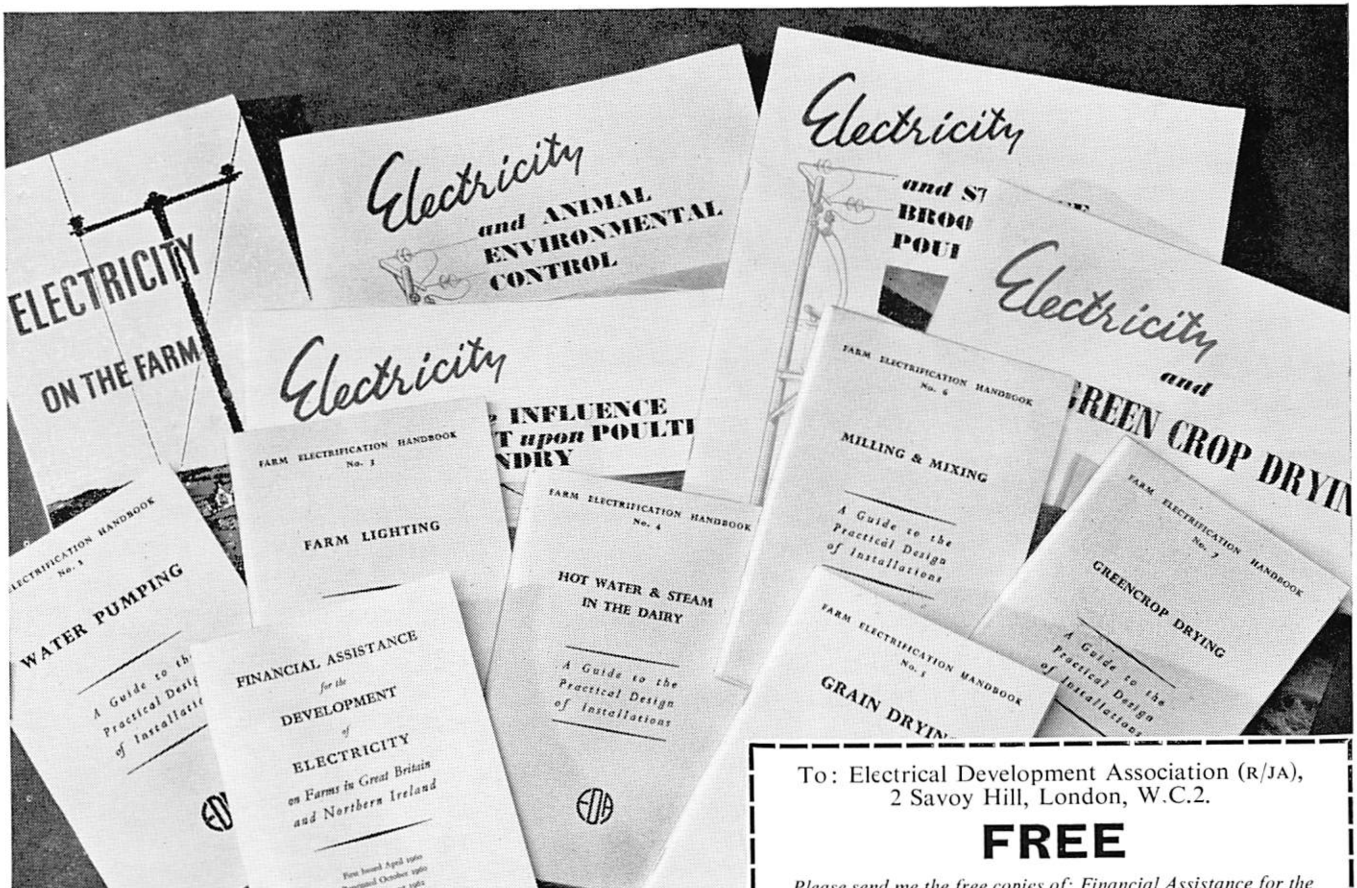

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LONDON OPEN MEETING – JANUARY 30th 1964

THE second all-day Open Meeting of the 1963/64 Session will be held at the Royal Society of Arts, John Adam Street, London, W.C. 2, on THURSDAY, JANUARY 30TH, 1964. The theme of the Conference is the "Improvement of Working Conditions for Farm Machinery Operatives," and will commence at 10.45 a.m. with the presentation of a Paper on "Noise," by Mr. S. W. R. Cox, B.Sc., Head of the Instrumentation Department of the National Institute of Agricultural Engineering. This will be followed at approximately 11.30 a.m. by "Operators' Position and Comfort," by Mr. A. K. Simons, Managing Director of the Bostrom Manufacturing Company, Limited. The Conference will re-convene at 2.15 p.m. to hear "Cabs and their Testing," by Mr. T. C. D. Manby, B.Sc., A.M.I.Agr.E., Head of Tractor Performance Department of the National Institute of Agricultural Engineering. Informal discussion will follow each Paper.

Admission to the Conference is free of charge to all Members and visitors (tickets are not issued). Pre-prints of the Papers may be obtained from the Secretary in early January, 1964.

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