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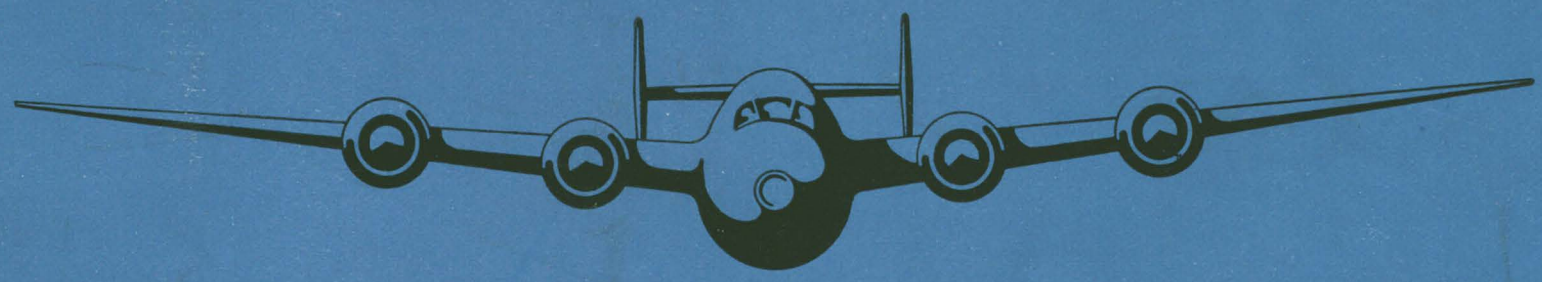

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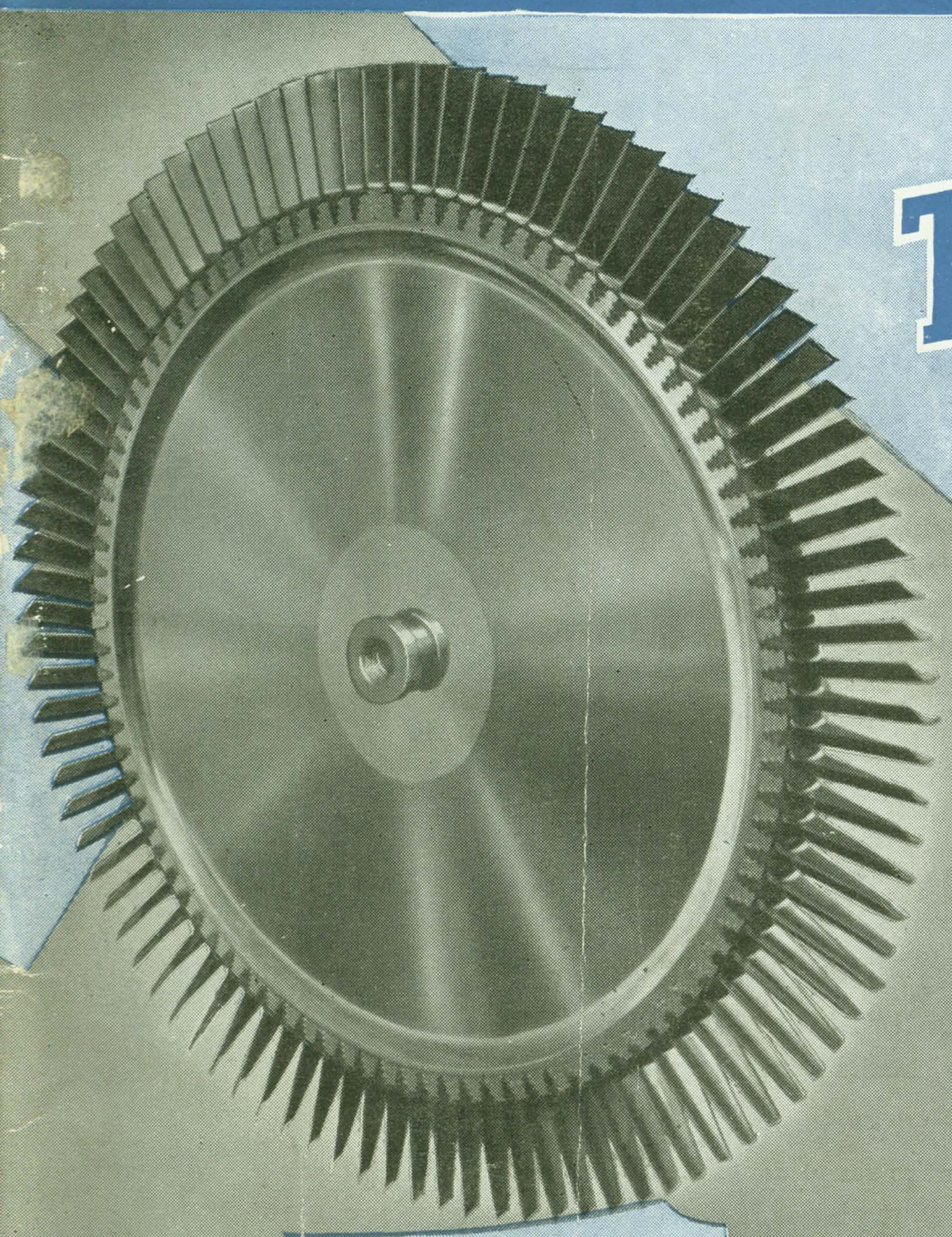

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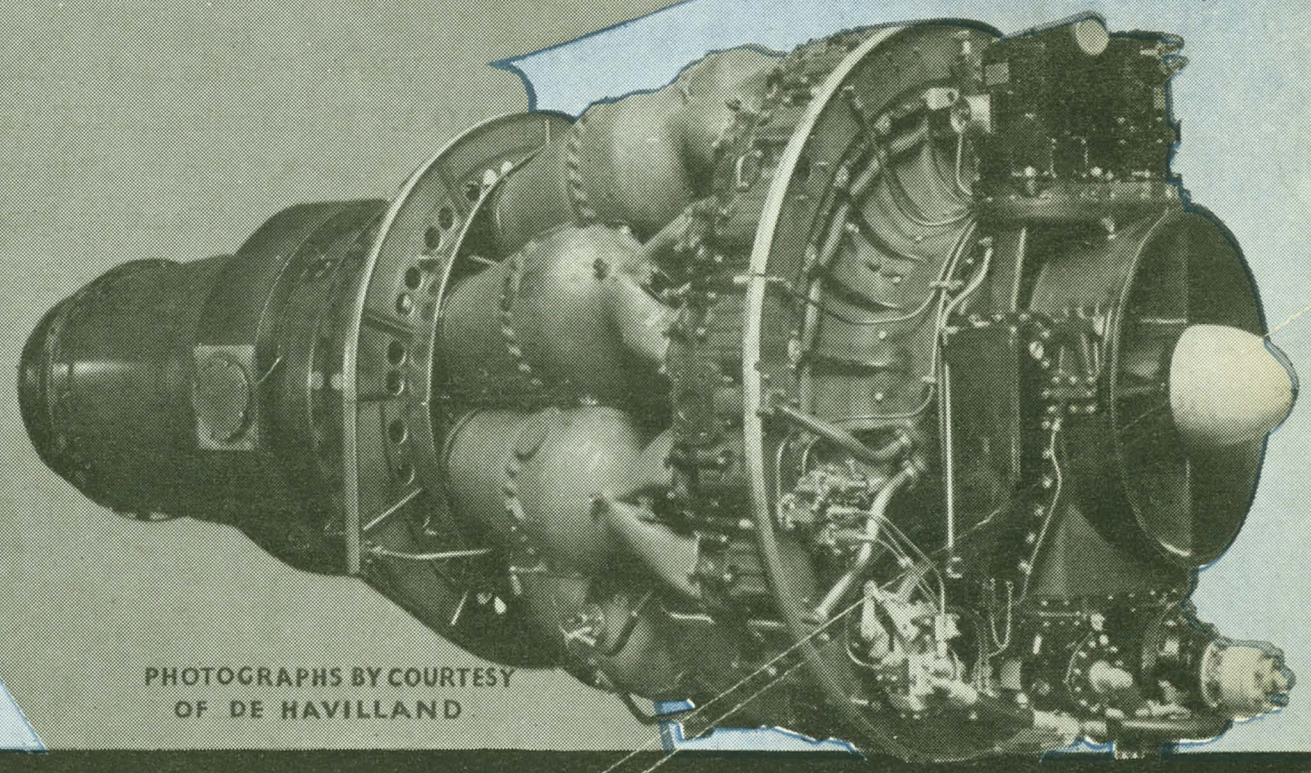

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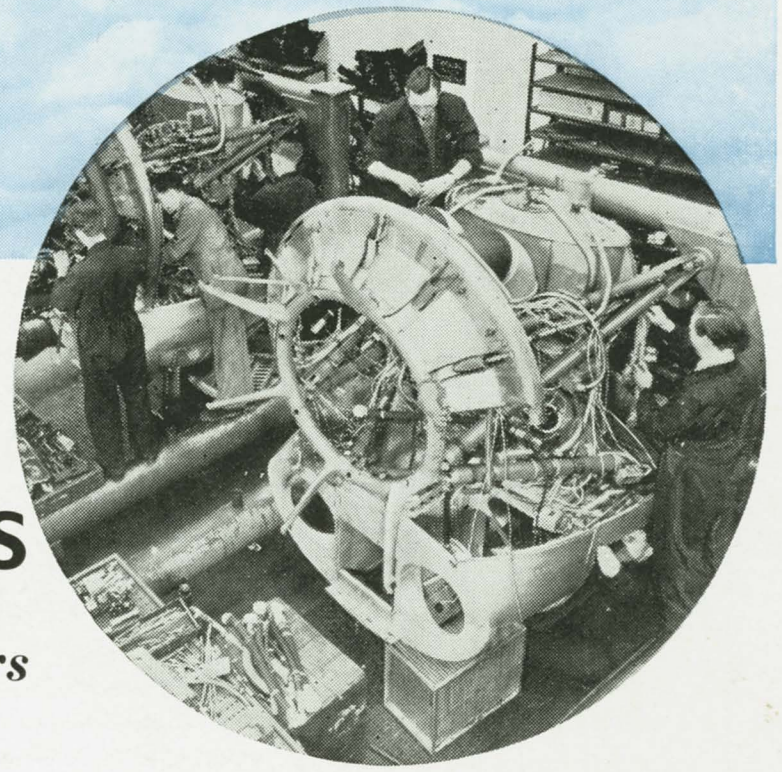

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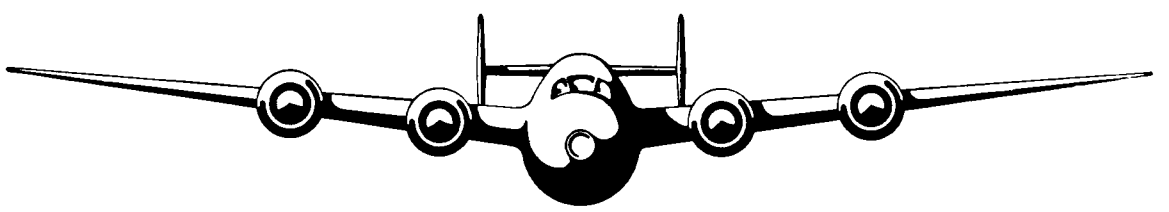

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Aircraft Engineering

Index to Volume XXIII

A

Aerodynamics:
Airflow Patterns in the Neighbourhood of Helicopter Rotors. J. M. Drees and W. P. Hendal 107, 137
Flight Characteristics at High Mach Numbers. V. Outman and G. V. Graff 139
Rotary Derivatives in Yaw. V. M. Falkner.. 44
Shock-Wave Shadow Photography. F. E. Lamplough 94, 153
Steepest Angle of Climb of Jet Aeroplanes. E. Järvineva 76
Viscous Effects in Compressible Fluids 83, 137
Air-Conditioning for Aircraft Cabins. R. Tourret and E. F. Winter 188
Air in Hydraulic Transmission Systems. D. Rendel and G. R. Allen 337
Air Registration Board Notices, 8, 58, 150, 237, 262, 271, 310
Airworthiness Requirements and Fatigue of Helicopters. J. Shapiro 32
Airworthiness Requirements. I.C.A.O. Operational Performance, K. G. Wilkinson .. 36
Airworthiness Type Record. Standardization of an Aircraft. I. M. K. Malik 361
Alexander, B. Methods of Spiral Spring Design 113
Allen, G. R., and D. Rendel. Air in Hydraulic Transmission Systems 337
Anglo-American Aeronautical Conference. The 254
Aspden, R. L. Electronic Flash Photography .. 354
Asymmetric Power. Flight on (*Correspondence*) 85
Ayers, K. B. An Application of the Three-Moment Equation to Continuous Beams .. 173

B

Beams Stressed Beyond the Elastic Limit. Moment of Resistance of. M. Ish Horowicz.. 9
Beams with Built-in or Elastically Constrained Ends. K. B. Ayers 173
Boddy, J. H., and K. J. Mackenzie. Fuel Testing in Gas-Turbines 40
Book Reviews:
Adhesion and Adhesives 373
Air Compressors, P. C. Bevis 149
Air Systems for Aircraft. C. A. H. Pollitt .. 149
Conquest of Space, The. W. Ley 149
Creep of Metals. L. Rotherham 282
Engineering Metrology. K. J. Hume .. 149
Fluid Pressure Mechanisms. H. G. Conway.. 149
German-English Technical Dictionary. K. F. Leidecker 281
Handbook of Experimental Stress Analysis. M. Hetenyi 86
Handy Technical Dictionary in Eight Languages 281
Introduction to Helicopter Aerodynamics. Vol. 1. W. Z. Stepniewski 86
Introduction to Servo-Mechanisms. A. Porter 281
Jane's All the World's Aircraft, 1950-51 .. 21
Grenzschicht Theorie. H. Slichting 347
Mechanics Applied to Vibrations and Balancing. D. L. Thornton.. 282
Metals at High Temperatures. F. H. Clark .. 112
Performance of a Piston-Type Aero Engine. A. W. Morley 347
Problems in the Theory of Viscous Compressible Fluids. G.A.L.C.I.T. .. 83, 137
Structure and Mechanical Properties of Metals. The. B. Chalmers 112
Books Received: 8, 38, 87, 112, 149, 211, 246, 282, 299, 336, 373
Bowey, G. S., and C. H. Cumberland. Water Systems in Civil Aircraft 322
Bowyer, E. C. Representing the British Aircraft Industry 250
Brailsford, G. R. Graphical Interpretation of Difficult Curves 156
Brailsford, G. R. Replacement of Masses and Areas by Equivalent Particles 330
Brake Energy Nomogram 244
Bristol 171 Helicopter. Development of the. F. W. Stokes 67
Bristol Brabazon. Twin-Centaurus Power-Plant for. J. C. Norton 124
British Aircraft Industry, Representing the. E. C. Bowyer 250
British Standard Specifications 151, 184, 278, 350

C

Cabins. Air-Conditioning for Aircraft. R. Tourret and E. F. Winter 188
Canada. Organization of Aeronautical Research in 243
Carline, A. J. K. Still-Air Range in the Stratosphere 292
Chalmette, M. English-French Vocabulary of Aeronautical Terms 117, 145, 179, 207, 239, 279
Civil Aircraft. Stalling Risks with (*Correspondence*) 111
Climb of Jet Aeroplanes. The Steepest Angles of. E. Järvineva 76
Cold Climates, Aero-Engine Oil Systems for. N. Sharp 368
Combustion Problems of the Gas Turbine. I. Lubbock 196
Compressible Fluids, Viscous Effects in 83, 137
Conference, The Anglo-American Aeronautical 254
Connolly, J. V. Production Engineering, Administration and Management 19
Correspondence .. 85, 111, 159, 238, 299, 378
Critical Flow of a Gas Through a Convergent Nozzle. V. D. Naylor 160, 238, 305, 378
Critical Flow, The Rapid Discharge of Gases from Vessels. J. Kestin and J. S. Glass .. 300
Critical Flow of a Compressible Gas with Friction. V. D. Naylor 308
Cumberland, C. H., and G. S. Bowey. Water Systems in Civil Aircraft 322
Curves, Graphical Interpretation of Difficult. G. R. Brailsford 156
Cylindrical Tubes under External Pressure, Failure of. R. C. C. Ringrose 138

D

Dissipation of Heat, A General Discussion on 311
Drees, J. M., and W. P. Hendal. Airflow Patterns in the Neighbourhood of Helicopter Rotors 107, 137

E

Educational Instruction Units, R.A.F... .. 43
Electrical Potential Difference Nomogram .. 29
Electronic Flash Photography. R. L. Aspden .. 354
Engines:
Combustion Problems of the Gas Turbine. I. Lubbock 196
Fuel Testing in Gas-Turbines. K. J. Mackenzie and J. H. Boddy.. 40
Fuels for Gas-Turbines. J. G. Sharp 2
Oil Systems for Cold Climates. N. Sharp .. 368
Twin-Centaurus Power-Plant for the Brabazon. J. L. Norton.. 124
Escalator Process, An Application of the. J. Morris 136

F

Falkner, V. M. Rotary Derivatives in Yaw .. 44
Fatigue of Helicopters. Airworthiness Requirements and. J. Shapiro 32
Flexural Axis, Flexural Centre and Shear Centre. R. Tatham 209
Flexural Stability of a Cantilever. Torque and the. J. Morris 375
Flight Characteristics at High Mach Numbers. V. Outman and G. V. Graff 139
Flight on Asymmetric Power (*Correspondence*) 85
Fluid Flow:
Critical Flow of a Gas through a Convergent Nozzle. V. D. Naylor .. 160, 238, 305, 378
Flow of a Compressible Gas with Friction. V. D. Naylor 308
Rapid Discharge of Gases from Vessels, The. J. S. Kestin and J. S. Glass 300
Fluids. Viscous Effects in Compressible.. 83, 137
French Aero Salon, The Nineteenth. J. H. Stevens 218
French Aeronautical Terms, Vocabulary of English-. M. Chalmette 117, 145, 179, 207, 239, 279
Fuel Testing in Gas-Turbines. K. J. Mackenzie and J. H. Boddy 40
Fuels for Gas-Turbine Aero-Engines. J. G. Sharp 2

G

Garvey, S. J. The Quadrilateral Shear Panel 134, 211
Gas Turbines, Combustion Problems of. I. Lubbock 196
Gas Turbines, Fuels for. N. Sharp 2
Gas Turbines, Fuel Testing in. K. J. Mackenzie and J. H. Boddy 40
Gas Turbines, High-Temperature Steels and Alloys for 78
Gases from Vessels, The Rapid Discharge of. J. Kestin and J. S. Glass 300
Glass, J. S., and J. Kestin. The Rapid Discharge of Gases from Vessels 300
Gliders for High Performance, The Design of. K. G. Wilkinson 263
Graff, G. V., and V. Outman. Flight Characteristics at High Mach Numbers 139
Grain Direction on Light Alloy Extrusions, Effect of. D. M. McElhinney.. 62
Grain Flow on the Strength of Lugs, Influence of. G. I. Robinson 257
Graphical Interpretation of Difficult Curves. G. R. Brailsford 156
Gust Investigation, The V-g Recorder for. C. V. G. Usher 235

H

Haerle, H. R. Pneumatics for Ancillary Power in Aircraft 272
Heat Transfer, A General Discussion on .. 311
Helicopter, Notes on the Development of the Bristol 171. F. W. Stokes 67
Helicopter Rotors, Airflow Patterns in the Neighbourhood of. J. M. Drees and W. P. Hendal 107, 137
Helicopter. The S.N.C.A.O. 376
Helicopters, Airworthiness Requirements and Fatigue of. J. Shapiro 32
Hendal, W. P., and J. M. Drees. Airflow Patterns in the Neighbourhood of Helicopter Rotors 107, 137
High-Temperature Steels and Alloys for Gas Turbines 78
Hydraulic Transmission Systems, Air in. D. Rendel and G. R. Allen 337

I

I.C.A.O. Airworthiness and Operational Performance Requirements. K. G. Wilkinson .. 36
Instructional Units, R.A.F. Mobile 43
Interplanetary Flight Vehicles. Fundamental Dynamics of. L. N. Thompson .. 228, 299
Interplanetary Flight. Orbital Space Vehicles for 334
Ish-Horowicz, M. Application of Plastic Theory to Bending, The 203
Ish-Horowicz, M. Moment of Resistance of Beams Stressed Beyond the Elastic Limit .. 9

J

Järvineva, E. The Steepest Angle of Climb of Jet Aeroplanes 76
Jet-Propelled Aeroplanes in the Stratosphere. Still-Air Range of. A. J. K. Carline 292

K

PAGE

Kelvin Medal, The 377
Kestin, J., and J. S. Glass. The Rapid Discharge of Gases from Vessels 300

L

Lamplough, F. E. Shock-Wave Shadow Photography 94, 153
Light Alloy Extrusions. The Effect of Grain Direction on Mechanical Properties of. D. M. McElhinney 62
Longitudinal Stability Fundamentals. M. L. Wisniewski 362
Lubbock, I. Combustion Problems of the Gas Turbine 196

M

McElhinney, D. M. Effects of Grain Direction on Light Alloy Extrusions 62
Mach Numbers, Flight Characteristics at High. V. Outman and G. V. Graff 139
Mackenzie, K. J., and J. H. Boddy. Fuel Testing in Gas-Turbines 40
Maintenance:
Sabena, Maintenance and Overhaul at. J. H. Stevens 163
T.W.A. Overhaul and Maintenance System, The. H. W. Perry 22
Malik, I. M. K. Torsional Column Strength of Thin-Walled Open Sections 211
Malik, I. M. K. Type Record. Standardization of an Aircraft 361
Marathon Reference Sheet 15, 51
Mathematics:
An Application of the Escalator Process. J. Morris 136
An Application of the Three-Moment Equation. K. B. Ayers 173
Graphical Interpretation of Difficult Curves. G. R. Brailsford 156
Methods of Spiral Spring Design. B. Alexander 113
Metals:
Effect of Grain Direction on Light Alloy Extrusions. D. M. McElhinney 62
Influence of Grain Flow on the Strength of Lugs. G. I. Robinson 257
Metal Potential-Difference Nomogram, A .. 29
Steels and Alloys for Gas Turbines. High Temperature 78
Morris, J. An Application of the Escalator Process 136
Morris, J. Torque and the Flexural Stability of a Cantilever 375

N

Naylor, V. D. Critical Flow of a Gas through a Convergent Nozzle 160, 238, 305, 378
Naylor, V. D. Flow of a Compressible Gas with Friction 308
Nightingale, J. The Determination of Orifice Parameters for Shock Absorbers 261
Nomogram, Brake Energy 244
Nomogram, Metal Potential-Difference .. 29
Norton, J. L. The Twin-Centaurus Power-Plant for the Brabazon 124

O

Oil Systems for Cold Climates, Aero-Engine. N. Sharp 368
Orbital Space Vehicles for Interplanetary Flight 334
Orifice Parameters for Shock Absorbers. The Determination of, J. Nightingale 261
Outman, V., and G. V. Graff. Flight Characteristics at High Mach Numbers 139

P

Paris Aero Salon 1951. J. H. Stevens 218
Passenger Aircraft. Water Systems in. C. H. Cumberland and G. S. Bowey 322
Passenger Cabins in Aircraft. Air-Conditioning for. R. Tourret and E. F. Winter 188
Patent Office, Month in the 28, 59, 91, 121, 153, 185, 215, 247, 289, 319, 351, 381
Patent Specifications, U.S. 30, 60, 92, 122, 154, 186, 216, 248, 290, 320, 352, 382
Perdue, J., and P. Person. The Semi-Articulated Multi-Wheel Bogie Undercarriage 104

PAGE

Performance in Climb of Jet Aeroplanes. E. Järvineva 76
Performance Requirements. I.C.A.O. Airworthiness and Operational. K. G. Wilkinson 36
Person, P., and J. Perdue. The Semi-Articulated Multi-Wheel Bogie Undercarriage 104
Photography, Electronic Flash. R. L. Aspden .. 354
Photography. Shock-Wave Shadow. F. E. Lamplough 94, 153
Plaskowski, Z. The Use of Auxiliary Rockets in High-Speed Aircraft 72, 159
Plastic Theory to Bending. The Application of. M. Ish-Horowicz 203
Pneumatics for Ancillary Power in Aircraft. H. R. Haerle 272
Power-Plant for the Brabazon, The Twin-Centaurus. J. L. Norton 124
Production Engineering, Administration and Management. J. V. Connolly 19
Professional Publications 18, 57, 66, 116, 149, 181, 210, 234, 271, 304, 333, 372

Q

Quadrilateral Shear Panel. The. S. J. Garvey 134, 211

R

R.A.F. Mobile Instructional Units 43
Range in the Stratosphere. Still-Air. A. J. K. Carline 292
Reaction-Powered Space Vehicles. Fundamental Dynamics of. L. N. Thompson 228, 299, 378
Reference Sheet. The Marathon .. 15, 51
Rendel, D., and G. R. Allen. Air in Hydraulic Transmission Systems 337
Replacement of Masses and Areas by Equivalent Particles. G. R. Brailsford 330
Research in Canada, Organization of Aeronautical 243
Research Reports and Memoranda:
Argentine 174
Australia 55, 174, 317, 348
Belgium 379
Canada 25, 55, 119, 147, 212, 241, 317, 348, 379
France 25, 55, 88, 174, 283, 348, 379
Germany 174
Great Britain 26, 57, 89, 120, 147, 176, 212, 241, 284, 318, 348, 379
Italy 174
Netherlands .. 25, 88, 175, 212, 241, 317, 380
Sweden 26, 55, 88, 175
U.S.A. 26, 55, 88, 119, 147, 175, 212, 283, 317, 349, 380
Yugoslavia 175
Ringrose, R. C. C. Failure of Cylindrical Tubes under External Pressure 138
Robinson, G. I. Influence of Grain Flow on the Strength of Lugs 257
Rocket-Powered Space Vehicles. Fundamental Dynamics of. L. N. Thompson .. 228, 299
Rockets in High-Speed Aircraft. The Use of Auxiliary. Z. Plaskowski 72, 159

S

Sabena, Maintenance and Overhaul at. J. H. Stevens 163
S.A.E. National Aeronautic Meeting, The .. 374
Sailplanes for High Performance, The Design of. K. G. Wilkinson 263
Shapiro, J. Airworthiness Requirements and Fatigue of Helicopters 32
Sharp, J. G. Fuels for Gas-Turbine Aero-Engines 2
Sharp, N. Oil Systems for Cold Climates .. 368
Shear Centre, Flexural Centre and Flexural Axis. R. Tatham 209
Shear Panel, The Quadrilateral. S. J. Garvey 134, 211
Shock Absorbers. The Determination of Orifice Parameters for. J. Nightingale 261
Shock-Wave Shadow Photography. F. E. Lamplough 94, 153
Society of British Aircraft Constructors, The. E. C. Bowyer 250
Society of British Aircraft Constructors, Aircraft Standards of the 339
Solvey, J. The Estimation of Wing Weight .. 143
Space Vehicles, Fundamental Dynamics of Reaction-Propelled. L. N. Thompson 228, 299, 378

PAGE

Space Vehicles for Interplanetary Flight .. 334
Spring Design, Spiral. B. Alexander 113
Stability Fundamentals, Longitudinal. M. L. Wisniewski 362
Stalling Risks with Civil Aircraft (*Correspondence*) 111
Standards of the S.B.A.C., The Aircraft .. 339
Stevens, J. H. Maintenance and Overhaul at Sabena 163
Stevens, J. H. Paris and Le Bourget 1951 .. 218
Stokes, F. W. The Development of the Bristol 171 Helicopter 67
Stratosphere, Still-Air Range in the. A. J. K. Carline 292
Stressing:
An Application of the Three-Moment Equation to Continuous Beams. K. B. Ayers .. 173
Failure of Cylindrical Tubes under External Pressure. R. C. C. Ringrose 138
Moment of Resistance of Beams Stressed Beyond the Elastic Limit. M. Ish-Horowicz 9
Plastic Theory to Bending. The Application of. M. Ish-Horowicz 203
Quadrilateral Shear Panel. The. S. J. Garvey 134, 211
Replacement of Masses and Areas by Equivalent Particles. G. R. Brailsford 330
Shear Centre, Flexural Centre and Flexural Axis. R. Tatham 209
Spiral Spring Design. B. Alexander 113
Torque and the Flexural Stability of a Cantilever. J. Morris 375
Torsional Column Strength of Thin-Walled Open Sections. I. M. K. Malik 211

T

Tatham, R. Shear Centre, Flexural Centre and Flexural Axis 209
Thompson, L. N. Fundamental Dynamics of Reaction-Powered Space Vehicles 228, 299, 378
Torque and the Flexural Stability of a Cantilever. J. Morris 375
Tourret, R., and E. F. Winter. Air-Conditioning for Aircraft Cabins 188
Tools for the Workshop .. 75, 151, 182, 183, 286, 287
Trade Announcements 14, 58, 90, 152, 182, 214, 246, 288, 310, 346, 360
Trade Publications Received 53, 90, 152, 184, 208, 288, 350, 367
Trade Reviews 21, 66, 106, 142, 150, 244, 346
The T.W.A. Overhaul and Maintenance System. H. W. Perry 22
Tubes under External Pressure, Failure of Cylindrical. R. C. C. Ringrose 138
Type Record, Standardization of Aircraft. I. M. K. Malik 361

U

Undercarriage, Brake Energy Nomogram .. 244
Undercarriage. The Semi-Articulated Multi-Wheel Bogie. P. Person and J. Perdue .. 104
Undercarriage Shock Absorbers. The Determination of Orifice Parameters for. J. Nightingale 261
Usher, C. V. G. The V-g Recorder 235

V

V-g Recorder, The. C. V. G. Usher 235
Vocabulary of Aeronautical Terms, English-French. M. Chalmette 117, 145, 179, 207, 239, 279

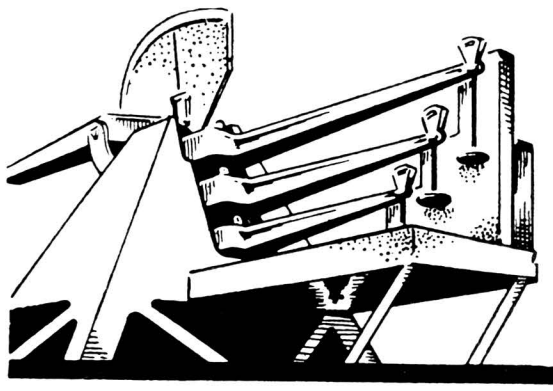
W

Water Systems in Civil Aircraft. C. H. Cumberland and G. S. Bowey 322
Weight. The Estimation of Wing. J. Solvey .. 143
Whirling Shafts. Torque and the Flexural Stability of. J. Morris 375
Wilkinson, K. G. I.C.A.O. Airworthiness and Operational Performance Requirements .. 36
Wilkinson, K. G. The Design of Sailplanes for High Performance 263
Winter, E. F., and R. Tourret. Air-Conditioning for Aircraft Cabins 188
Wisniewski, M. L. Longitudinal Stability Fundamentals 362

Y

Yaw, Rotary Derivatives in. V. M. Falkner .. 44

Biblioteka Główna



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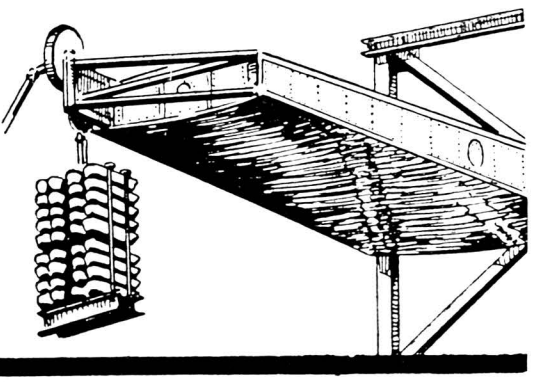

VOL XXIII No 263 JANUARY 1951

An Abstraction

IN this issue PROFESSOR J. V. CONNOLLY brings to a conclusion the series of articles on Production Engineering, Administration and Management which have been written at our invitation and the publication of which we started in May last year.

A Neglected Subject

In connexion with them a tribute should, we think, be paid to the imaginative foresight shown by the Governors of the College of Aeronautics at Cranfield in instituting a chair of Aircraft Economics and Production, of which he is the first occupant. The subject is one which is widely covered in the curricula of a large number of universities in the United States of America, but has been, until recently, much neglected in this country and, indeed, we are not ashamed to say that we could not state in answer to an inquiry where else in England courses on production and management can even now be taken. Not ashamed, because we doubt if many ordinarily well-informed people could produce the information with the same readiness that, for instance, they would reel off a list of places where the student can receive tuition in engineering.

Putting in a Claim

We, on the other hand, have no need to be ashamed of the patronage we ourselves have given to this matter even prior to the commission of PROFESSOR CONNOLLY's series and can hold up our heads with some pride as we point to the by no means negligible list of titles, dating back to 1942, given under the heading 'Works Administration' in the consolidated index to the contents of AIRCRAFT ENGINEERING in our booklet '1929-1950'. We might be pardoned, for instance, if we mention with gratification the recognition of the encouragement we gave him in supporting him in his investigations of the subject by publishing a series of articles from his pen which MR D. TIRANTI accorded to us in the preface to his book on *Production Control* published by CHAPMAN & HALL in 1946. In that series the author was more concerned with the actual technique of the planning and control of production as a matter of detail and did not attempt the wider purview that has been achieved in the present series.

A Popular Account

PROFESSOR CONNOLLY has advisedly confined himself to a very general survey of his subject intended for the aeronautical engineer rather than the specialist—whether in administration, management or production. Indeed, there is in actual fact little specifically aeronautical in his thesis and it can well be read with interest and profit by any engineer whatever his product.

In his concluding chapter our author gives an interesting summary of the respective function of Administration and Management—the former being responsible for the determination of objectives and policies which the latter is charged with converting into practical results. This is in a compressed form a restatement of the fuller definitions of the delimitation between them which he gave in his introductory chapter last May; the chain of responsibility for control of the output of the actual operatives being completed by what he calls 'Functional Officials', who provide the knowledge, skills and techniques necessary for the performance of the policies.

An Imprecise Vocabulary

The primary difficulty of anyone writing on, or teaching, this subject is that it has not as yet developed to the stage where terms are used with very precise, or at any rate agreed and standardized, meanings and the best the individual can do is at the outset to state clearly the sense in which he himself uses them, which PROFESSOR CONNOLLY has been most careful to do. This is perhaps only another way of saying that, as he puts it, the functions of Administration and Management are still in, if we may so express it, the inchoate stage of being arts and have not yet developed into becoming sciences.

We trust that we shall not be accused of being too metaphysical (in the sense of 'over-subtle') if we say that we ourselves have always had a liking for the word 'philosophy' since it was used by a friend some years ago to describe the state of development of another branch of knowledge which had not, in his opinion, reached the dignity of being a science.

Dictionary Meanings

Having written which, it is, we suppose, incumbent on us to try to specify what connotation in each case we ourselves intend by these three words. Turning to the dictionary, we find a definition of 'Philosophy' which is we feel pat to our purpose. It is, 'love of knowledge which deals with the most general causes and principles of things' and is opposed to 'Science' which is defined as, 'systematic and formulated knowledge; organized body of the knowledge that has been accumulated on a subject admitting of quantitative treatment'. With these meanings attached to the two terms we venture to say that 'philosophy' is precisely applicable to a subject such as that with which PROFESSOR CONNOLLY is dealing, as compared with, say, the 'science' of aeroplane design.

Confusing the Issue

'Art', we find, is primarily 'human skill as opposed to nature; a branch of learning serving as intellectual instrument for more advanced studies' which he may, or may not, take as the justification for his adoption of the word. It is only fair perhaps to mention that a still further subsidiary meaning is given by our dictionary. This is, 'practical application of any science'. Where this lands us we should not like to say and on the whole it seems wise to abandon there our efforts at precision of nomenclature.

Fuels for Gas-Turbine Aero-Engines

An Examination of the Performance Requirements and Attributes and Availability of Suitable Fuels

By J. G. Sharp

INTRODUCTION

THE advent of gas-turbines as power plants for military and civil aircraft has demonstrated certain actual and potential advantages over the use of conventional piston engines which ensure the increased adoption and importance of this type of prime mover. This increased use of gas-turbines in the aircraft field has necessitated careful reconsideration of the fuel supply position in the light of the new engine requirements. It is clear therefore that a detailed knowledge of all aspects of fuel performance in gas-turbine-powered aircraft is needed in order to enable the necessary usable fuel supply position to be assessed, and any resulting problems to be surmounted.

This paper has the purpose of reviewing and contributing to existing knowledge in this respect, and contains information based largely on the results of work undertaken at the Aero-Engine Laboratory at Thornton, Cheshire, where gas-turbine combustion and general problems have been studied since 1943.

In discussing the requirements which aircraft gas-turbine fuels must satisfy, it has been found convenient to separate them into two sets—those arising from the performance needs of the engines, and those arising from the problems associated with supplying the fuel from the aircraft tanks to the engine combustion chambers.

FUEL PERFORMANCE IN AIRCRAFT GAS-TURBINES

The fuel supplied to an aircraft gas-turbine is burned usually in a number of combustion chambers which must be capable of functioning satisfactorily under operating conditions varying over wide ranges—those shown in TABLE I being typical.

TABLE I

Parameter	Range of Values
Air pressure	3 to 70 lb./sq. in
Air temperature	−40 to +250° C.
Air flow	0·3 to 5·0 lb./sec.
Overall air/fuel ratio	<40 to 200
Fuel flow	0·020 to 0·125 lb./sec

Contemporary combustion chambers can be divided broadly into two main types characterized by the method of injecting the fuel into the combustion zone, these being the 'spray' and 'vaporizing' types. The former is at present by far the more widely used. Typical chambers of each type are illustrated diagrammatically in FIGS. 1 and 2.

The wide ranges of conditions given in TABLE I necessitate careful design in order to secure a satisfactory performance from the combustion chamber. The requirements are as follows:

(*a*) adequate combustion efficiency,
(*b*) adequate stability performance,
(*c*) smooth operation,
(*d*) quick, easy ignition even under adverse conditions,
(*e*) adequate combustion intensity,
(*f*) low pressure loss,
(*g*) satisfactory outlet temperature distribution,
(*h*) combustion products which harm no engine components,
(*i*) freedom from harmful deposits.

The degree of air control and turbulence which is necessary in a chamber in order to achieve the required combustion efficiency, intensity and stability leads to a loss of total pressure from the air passing through it which is equivalent to a loss of compressor efficiency and as such has a deleterious effect on engine performance. A compromise between the various performance criteria is therefore necessary, and one object of fuel research is to assess the extent to which this compromise can be beneficially affected by fuel properties.

The above performance criteria are discussed in detail as follows:

1. Combustion Efficiency

Combustion efficiency can be defined as the amount of heat derived within the physical limits of the chamber from a given quantity of fuel, expressed as a percentage of the theoretical heat release obtained if complete combustion of the fuel could be achieved.

There are several methods available for the assessment of combustion efficiency, and of these only two are extensively used, depending on (*a*) temperature measurements and (*b*) gas analysis respectively.

For some experimental work, and particularly for the development of combustion chambers, method (*a*) offers certain advantages. It is easy to use and gives results sufficiently rapidly and accurately for these purposes. The combustion efficiency by this method is defined, normally, as the actual gas temperature rise between inlet and outlet of the chamber expressed as a percentage of that which would be obtained theoretically from complete combustion of the fuel. For this purpose the exhaust gas temperature is determined by traversing the chamber outlet with a stagnation thermocouple and a mean temperature computed from readings 'weighted' if necessary in accordance with the gas flow at each traverse point. The method enables the exhaust temperature distribution to be obtained, but there are difficulties connected with temperature, air flow and other measurements which limit its accuracy.

For more exact work it is better to use method (*b*) which, though less rapid in operation than method (*a*), is nevertheless much more accurate and informative. The main difficulties of method (*a*) are avoided, the two remaining being those of obtaining sufficiently representative samples of the exhaust gases, and of analysing the samples with sufficient accuracy. By use of suitable techniques these difficulties have been overcome, and it is now possible to assess combustion efficiencies to about 0·2 per cent accuracy. Further, a knowledge of the composition of the exhaust products gives information about the distribution of combustion loss between such constituents as carbon monoxide, hydrogen and unburnt liquid or gaseous hydrocarbons, etc. Interpretation of such information may eventually lead to a better understanding of the cause of combustion loss.

One result of the wide range of operating conditions shown in TABLE I is the very wide range of fuel flows which is required from the fuel atomizer. Due to fuel system limitations this frequently means that poor fuel atomization is obtained at the relatively low flow conditions occurring at high altitudes. FIG. 3 gives a combustion efficiency curve for such an air flow (obtained using gas analysis) covering air/fuel ratios ranging beyond the normal engine requirements, and illustrates the way in which the combustion loss distribution varies with air/fuel ratio. It should be noted that above an air/fuel ratio of about 140/1 the loss is due predominantly to unburnt hydrocarbons, this being largely a result of very poor fuel atomization.

At engine cruising speed, the overall air/fuel ratio is usually in the region of 70/1, and fuel atomization is satisfactory under these conditions for giving a relatively low combustion loss which

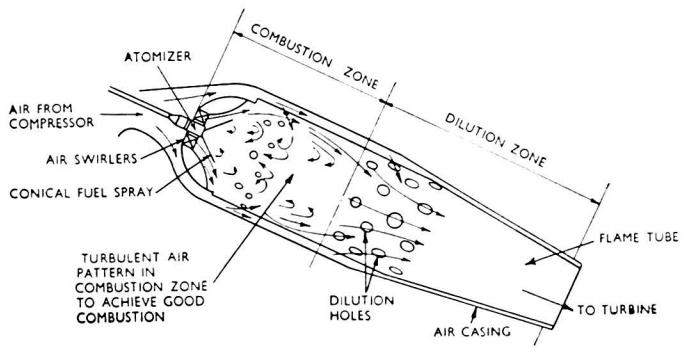

Fig. 1.—Typical spray-type combustion chamber

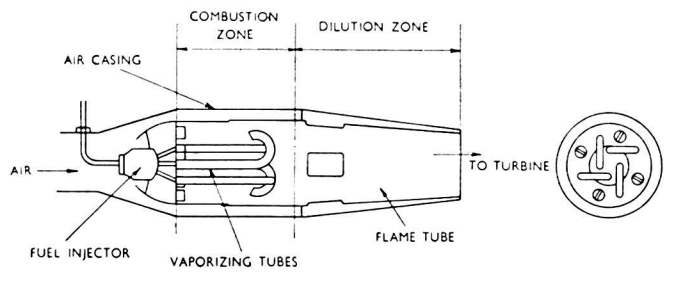

Fig. 2.—Typical vaporizing-type combustion chamber

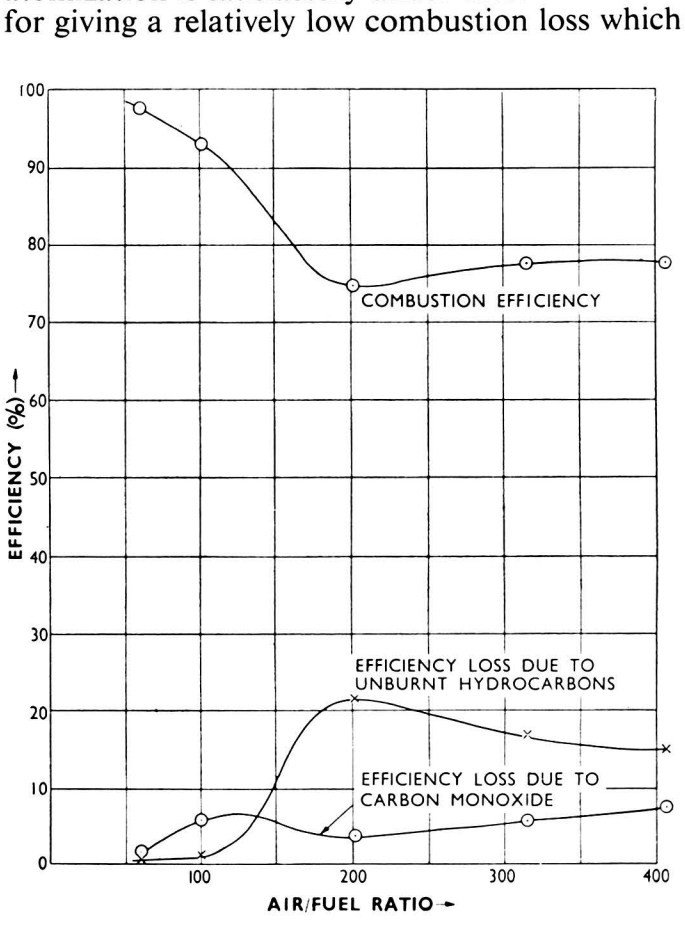

Fig. 3.—Distribution of combustion loss in a spray-type combustion chamber

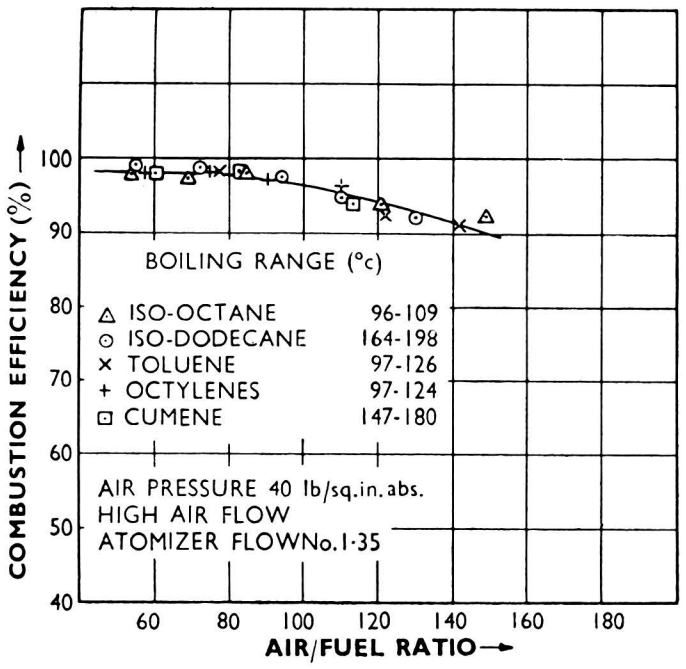

Fig. 4.—Comparison of fuels of different types and volatilities

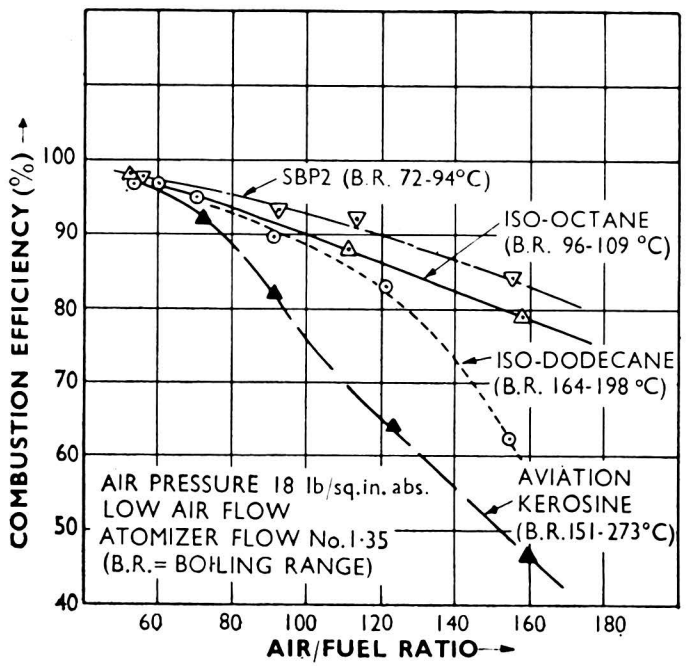

Fig. 5.—Comparison of paraffinic fuels of different volatilities

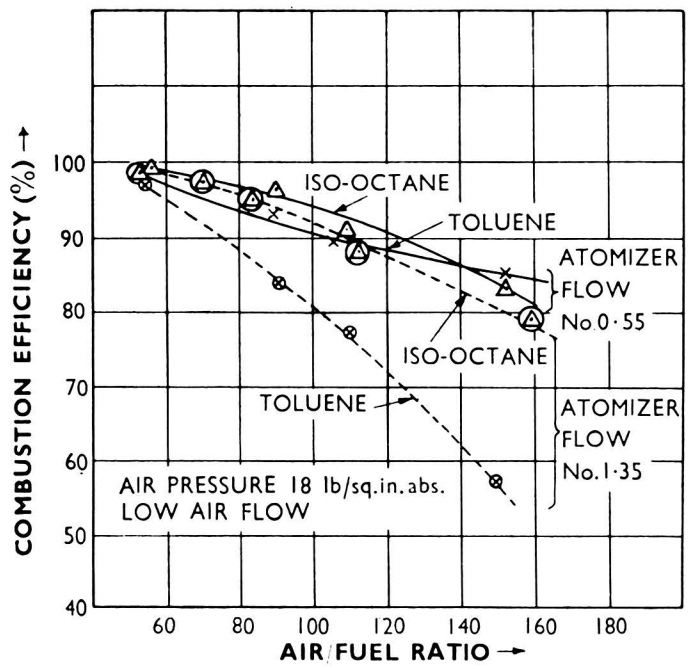

Fig. 6.—Comparison of an aromatic and paraffinic fuel with similar volatilities

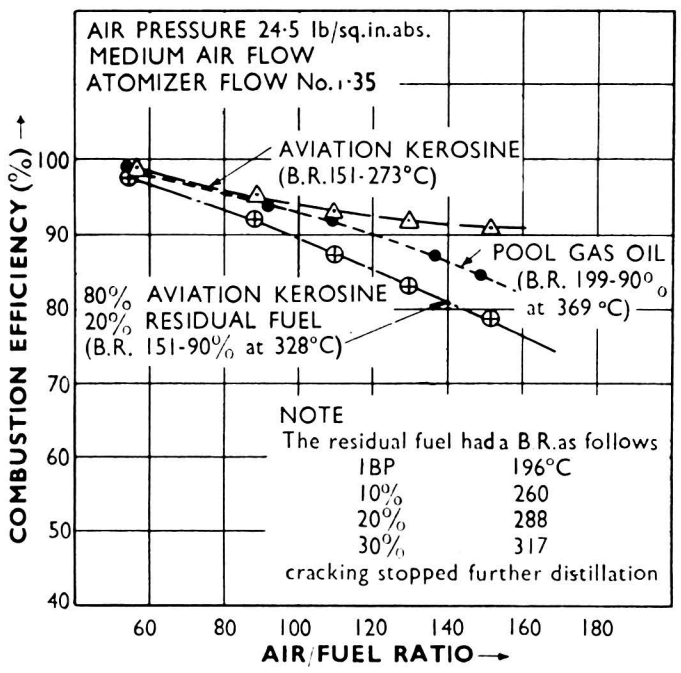

Fig. 7.—Effect of heavy fuel fractions

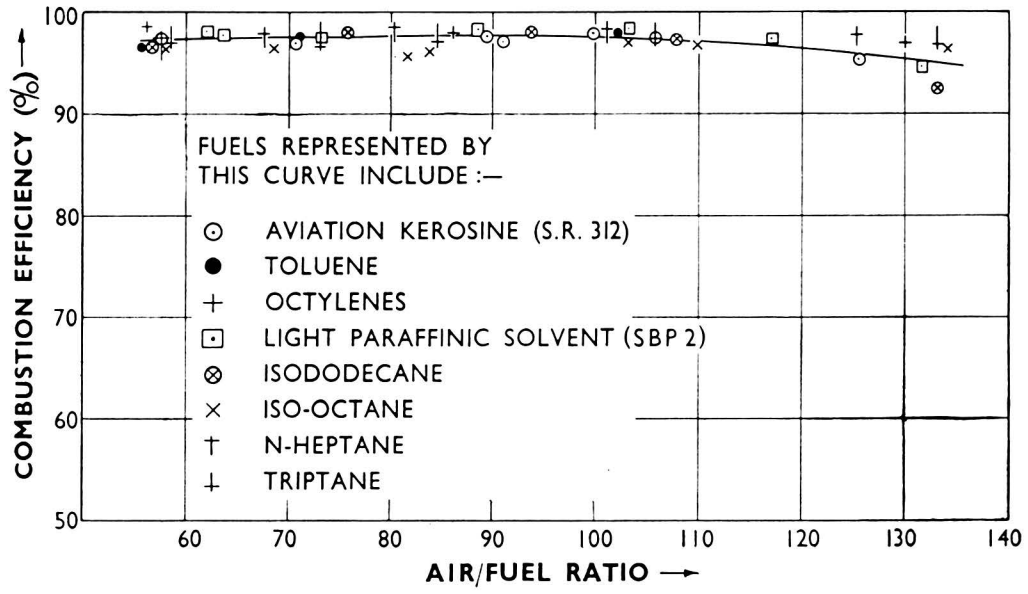

Fig. 8.—Typical efficiency curve for vaporizing type combustion chamber

lies predominantly in carbon monoxide formation.

By the use of method (*b*), supplemented by use of method (*a*) when required, combustion efficiency tests have been carried out on typical gas-turbine combustion chambers for the purpose of investigating the effects on combustion efficiency of fuel physical and chemical properties. The fuels selected for this work have been such as to embrace (in terms of their properties) any likely to be met in aircraft practice, bearing in mind such service limitations as freezing point, vapour lock and evaporation losses.

When using spray-type chambers it has been found that in the majority of cases performance can be related to factors affecting the evaporation of the fuel sprays—improvements in the rate of evaporation normally leading to improved combustion efficiency. Thus fuel properties of importance from the point of view of combustion efficiency are viscosity and density in their effects on atomization, and volatility (particularly 'heavy-end' volatility) in its direct effect on fuel evaporation. There is also evidence to show that under some conditions characterized by very poor atomization, a fuel which is easily cracked is advantageous.

In general, at high combustion chamber air throughputs (which normally imply reasonably good fuel atomization and evaporation) efficiency remains high over a sufficiently wide range of air/fuel ratios, and only insignificant differences due to fuels are found. At low throughputs however (normally implying relatively poor fuel atomization and air mixing) performance deteriorates and differences between fuels increase rapidly with increasing air/fuel ratio. Under the latter conditions, however, poor efficiency can usually be improved by better fuel atomization.

FIGS. 4-7 give typical combustion efficiency curves which illustrate the above points.

Results of tests performed on a vaporizing-type combustion chamber have also indicated that if adequate fuel vaporization is achieved, efficiency is at a high level, and differences due to fuels are small over the normal operating range of air/fuel ratios. Typical results are given in FIG. 8.

The evidence obtained so far shows that for spray type chambers, good combustion efficiency is possible provided adequate atomization of the fuel is achieved. Since viscosity can have important effects on atomization it is evident that for a particular combustion system there will be an upper fuel viscosity limit above which combustion will be come unsatisfactory. In specifying a fuel it would therefore appear necessary to limit viscosity to some maximum value at the lowest fuel temperature likely to be encountered in practice. Tests and experience have yet to show what this value is, but it is likely to be not less than 15 centistokes in view of the efficiency of modern atomizing techniques. Such a limitation would govern to some extent the distillation characteristics allowable, in view of the broad relation between these and viscosity.

Fuel viscosity is likely to be of minor importance in affecting combustion in well-designed vaporizing chambers. Pour point or cloud point are the more likely limitations in this case.

There is some additional evidence that at low air pressures corresponding to high altitudes, changes in the combustion properties of air/vapour mixtures can adversely affect the performance of contemporary combustion chambers of both types. The properties mainly concerned are probably the static combustion limits, which normally become narrower as pressure is reduced, and the ignition delay period which increases at the lower pressure.

To summarize, it appears that suitable design of combustion and atomizer systems can practically eliminate efficiency differences due to likely aircraft fuels, and that in contemporary designs this has already been achieved over a large part of the range of operating conditions, which includes engine cruising and full speeds up to high altitudes. Thus as far as combustion efficiency is concerned, aircraft gas-turbines are not selective of fuels provided that these can be atomized and vaporized adequately, and this is dependent ultimately on the low-temperature physical characteristics of the fuel—i.e. viscosity, pour point and cloud point.

2. Stability

The stability range of a combustion chamber is normally defined as the range of air/fuel ratios over which combustion in it is possible. It is important that for the purposes of acceleration and deceleration the range is sufficiently wide to allow of large rapid changes of fuel flow to the chamber without flame extinction. Stability limits under given conditions are decided largely by the combustion chamber air-flow pattern, and for contemporary chambers are adequate at most conditions. At low pressures, however, corresponding to very high engine altitudes, stability performance deteriorates and eventually becomes inadequate for engine purposes. This is largely a fundamental difficulty, although good design might alleviate it somewhat.

In the case of spray-type chambers, fuel properties appear to have some effect on the weak limits under certain conditions—i.e. the more volatile the fuel the weaker the possible combustion. However these effects normally occur when fuel atomization is relatively poor, and the evidence suggests that with modern improvements in design to give good atomization over the required engine working range, any advantage

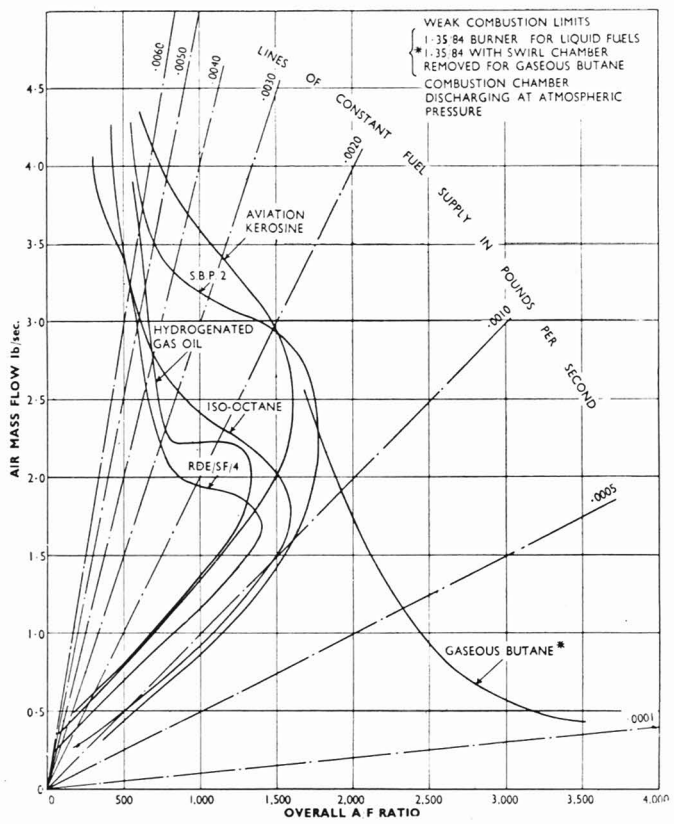

Fig. 9.—Typical weak extinction curves for a spray-type combustion chamber

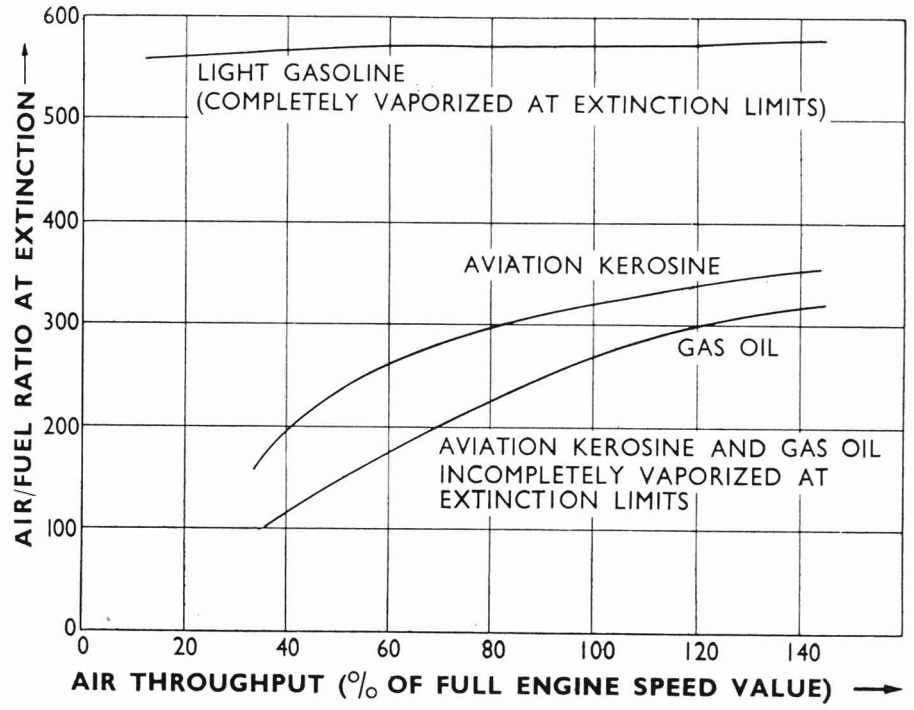

Fig. 10.—Typical weak extinction curves for a vaporizing type combustion chamber

to be gained by using relatively volatile fuels is likely to be slight.

With regard to vaporizing combustion systems, any large performance differences due to fuels are likely to be caused by the inadequacy of the vaporizer to vaporize the heavier fuels completely. Provided complete vaporization of the fuel is achieved, any practical differences due to fuel properties are likely to be small.

Curves showing relative weak stability performance using different fuels are shown in FIGS. 9 and 10.

Smoothness of Operation

The continuing smooth functioning of combustion chambers under all operating conditions is a necessary achievement and one which has been attained in most present designs. No occurrence of phenomena analogous to detonation in reciprocating engines has yet been established. 'Rough' running, when it occurs, is due usually to poor mixing conditions, but it can be caused by an oscillating fuel spray or flucutating fuel or air flow. Under some conditions the roughness has vibrations associated with it which can resonate with the air passing through the engine, or with parts of the engine or aircraft structure, preventing satisfactory engine operation. In some cases, with no apparent warning, complete temporary breakdown of the air-flow pattern inside an engine combustion chamber or chambers can occur, resulting in sudden loss of power.

There is some evidence that roughness, where it occurs, increases with increased fuel volatility, and this consideration should be borne in mind if, in emergency, the use of fuels more volatile than normal is likely. It is considered that the cure for most troubles of this kind lies in improved design.

Starting

The initiation of combustion in gas-turbine combustion systems is normally accomplished electrically, and for spray-type systems three main types of ignition source have been used:

(*a*) direct ignition of main fuel spray by high-tension spark,
(*b*) spark ignition of a subsidiary fuel spray, which then ignites the main spray, i.e. the torch igniter,
(*c*) surface discharge plug (giving a low-tension high-energy discharge).

Apart from the nature of the ignition source, there are other factors which determine the ease of ignition of a fuel spray:

(i) the degree of atomization under starting conditions,
(ii) the fuel volatility,
(iii) the relative locations of ignition source and fuel spray,
(iv) the temperature conditions,
(v) the air-flow pattern in the combustion chamber.

Fuel characteristics can influence (i) and (ii) directly and the other factors are likely to affect the relative starting performance when using different fuels. The influence of atomization and volatility for example, is likely to be less marked when using a torch igniter than when using direct spark ignition.

Experiments have been carried out using direct spark ignition, to ascertain the effects of fuel characteristics on starting performance, and the results of these are summarized in FIG. 11. In this figure, the minimum fuel pressure necessary for ignition at a given air throughput and starting temperature has been plotted against the fuel 10 per cent recovery temperature.

The curve shows directly the influence of the 10 per cent temperature—the more volatile the fuel, the easier the ignition. Although this curve does not differentiate between volatility and viscosity, there is reason to believe that in this case the effects of viscosity on atomization were small, and that the relationship shown is due largely to volatility.

With regard to the practical importance of this result, the more recent developments in fuel atomizers and ignition systems have largely, if not entirely, eliminated the advantage to be gained in starting by using fuels of relatively high volatility. For example, it has been found possible satisfactorily to ignite a modern combustion system up to very high altitude conditions by use of the surface discharge plug, and using aviation kerosine as fuel. Such a performance would have been quite impossible with earlier systems.

As mentioned earlier, fuel viscosity can have important adverse effects on atomization when it becomes sufficiently high. It is, of course, important that fuel viscosity never attains a value which prevents atomization adequate for engine starting or idling being achieved at the lowest fuel temperatures likely to be encountered. The maximum allowable value has yet to be found from tests and experience, but it is likely to be fairly high due to the efficiency of modern starting and atomizing techniques, and is not likely to be less than about 15 centistokes.

Typical viscosity-temperature curves for hydrocarbon fuels are given in FIG. 12.

Vaporizing-type chambers normally require the use of torch igniters in order that the vaporizers can be heated sufficiently for the initial vaporization of the fuel. Here again, given a correctly disposed igniter in a well-designed chamber, the problem reduces to that of igniting the igniter fuel spray, and is therefore subject to similar considerations as above.

The several combustion chambers of a typical aero-gas-turbine are connected together by interconnecting tubes which serve for ignition of those chambers containing no igniters. Under low-pressure conditions at altitude, ignition of some of these chambers via the interconnectors may not occur. The problem of ensuring ignition is considered to be primarily one of design which will not be greatly affected by fuel considerations.

Combustion Intensity

Combustion intensity is defined as the heat released per hour per cubic foot of combustion chamber volume for each atmosphere pressure of the combustion air. The higher the intensity that can be achieved, the smaller can be the engine combustion chambers for a given heat release, and consequently the lighter the engine. The degree of intensity is determined, broadly, by the air mixing pattern and degree of turbulence and the combustion properties of the combustible mixture.

It appears likely that for a given fuel a raising of intensity figures will be achieved gradually in the course of chamber development. Any further improvement that may be possible by correct exploitation and modification of fuel properties remains to be determined.

Pressure Loss

The total pressure loss from the air passing through a combustion chamber derives, broadly, from two main sources—the mixing and turbulence required to achieve satisfactory combustion, and the fundamental loss due to the heating of the air by combustion. Pressure loss from the second source is irreducible, but development

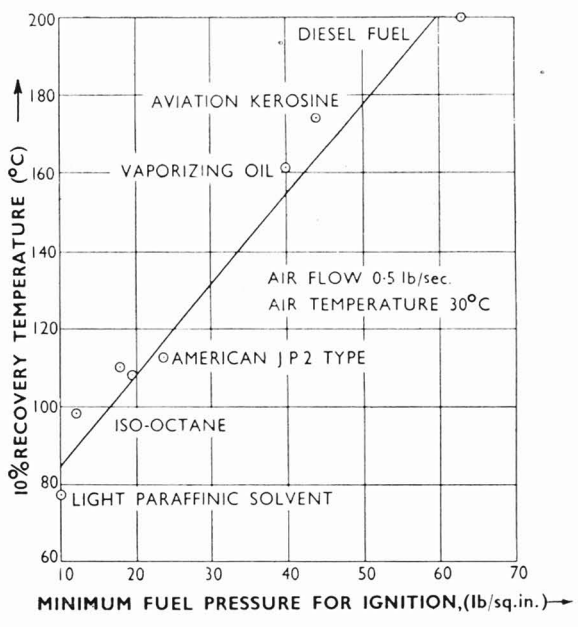

Fig. 11.—The effect of fuel volatility on starting characteristics

can reduce that arising from the first, which in most contemporary chambers contributes the larger part of the total loss.

Fuel properties can have only indirect effects on pressure loss in that any improvement in combustion performance due to fuel properties can be sacrificed, if necessary, in order to reduce the turbulence and mixing which cause the loss.

Exhaust Temperature Distribution

The attainment of a satisfactory combustion chamber exhaust temperature distribution is important since poor distribution can have adverse effects on the life of the turbine nozzles and blades.

There is some evidence that the degree of fuel atomization and fuel volatility can affect the distribution from a particular chamber to some extent, but the air mixing pattern in the dilution zone has the major influence, and this can usually be modified where required to achieve the necessary standard of distribution.

Corrosion and Erosion due to Combustion Products

The gases issuing from combustion chambers usually contain products which are harmful to engine components such as the turbine nozzles and blades, or the chambers themselves, in varying degrees. These products can produce their effects in two ways—by corrosion and by erosion.

Corrosion in aero-gas-turbines, where it has occurred, has been associated usually with the amount of sulphur compounds in the fuel. Information on this point is relatively scanty, and that available shows that no serious trouble has been experienced from this source, but it should be emphasized that by far the greater amount of engine running has been carried out using fuels containing relatively little sulphur—of the order of 0·08 per cent. Since the maximum amount of sulphur allowable in a fuel from an engine viewpoint might have a bearing on fuel production difficulties and cost it is essential that this amount be known, and it is in fact the subject of investigations now in progress. Evidence already available suggests that the acceptable maximum sulphur content need not be less than about 0·3 per cent.

Although erosion of turbine components has been experienced in some cases, it has not necessarily been attributable to combustion products such as carbon or ash, and in the main has been more likely due to dust, etc., in the atmosphere.

Deposits

Deposits in a gas turbine combustion chamber can, if in sufficient quantity, interfere seriously with its performance and reliability. For example, performance may be adversely affected by interference with the aerodynamics of the chamber, and the creation of large local temperature gradients in the material may result in loss of reliability due to distortion and fretting. Deposits are derived mainly from two sources—ash in the fuel and carbon liberated during combustion. As far as aero gas-turbines are concerned, little trouble has been experienced from ash since most of the fuels used have had low ash contents.

In the past, however, considerable trouble has been experienced from carbon deposits, which can occur in different forms in various regions of the flame tube. In the type of chamber illustrated in FIG. 1 for example, deposits in the combustion zone generally occur as a thin lacquer over the metal surfaces, or as lumps in relatively stagnant regions such as the tip of the atomizer air shroud. The air shroud is used to blow air over the atomizer face and so prevent carbon deposition here which would otherwise seriously foul the fuel spray. Carbon also tends to be deposited on the igniter, thus causing faulty ignition if this is of the high-tension type, and sufficient air must be passed over the electrodes to prevent this. Frequently, hard thin dense layers of carbon

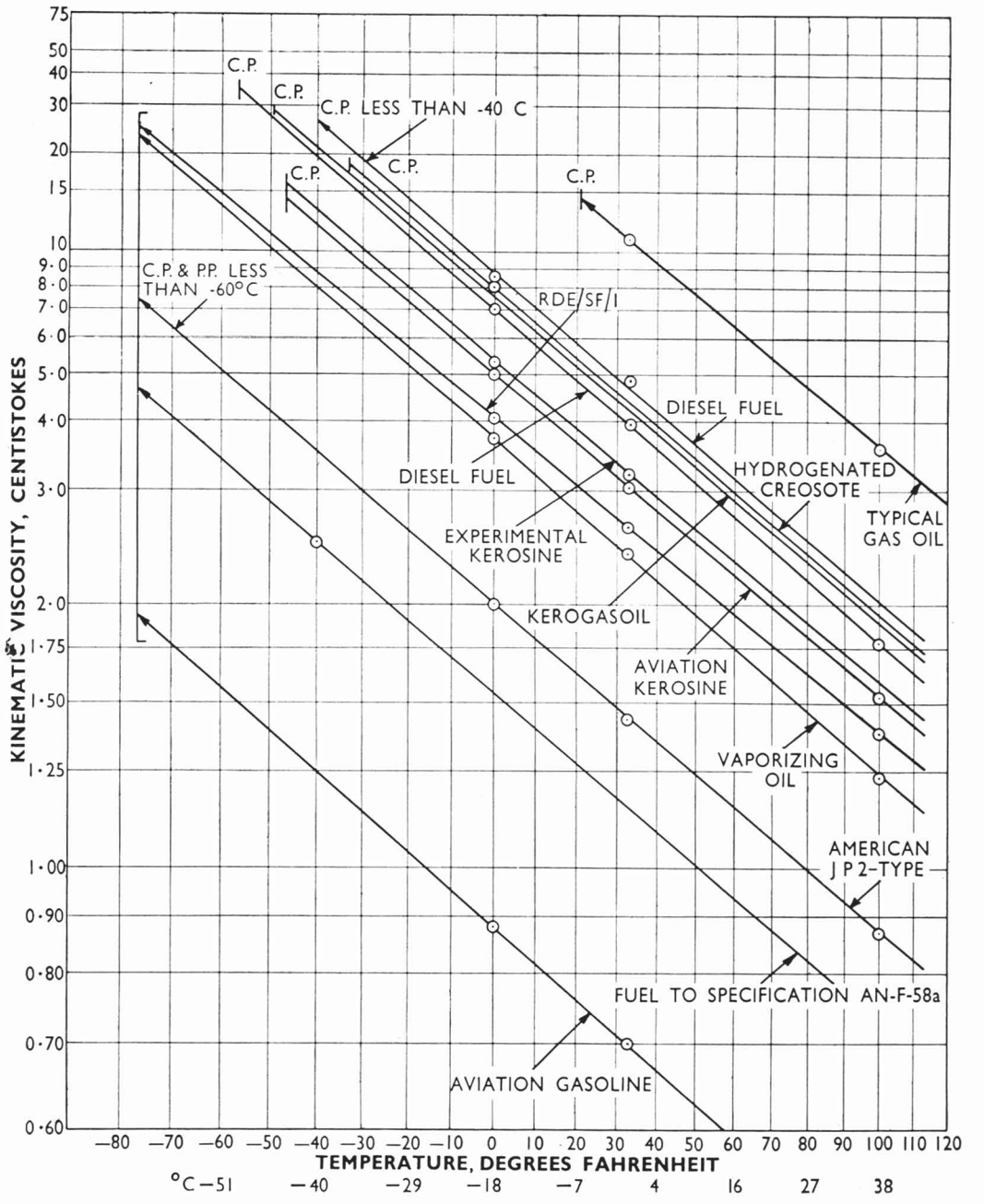

Fig. 12.—Typical viscosity/temperature curves for hydrocarbon fuels

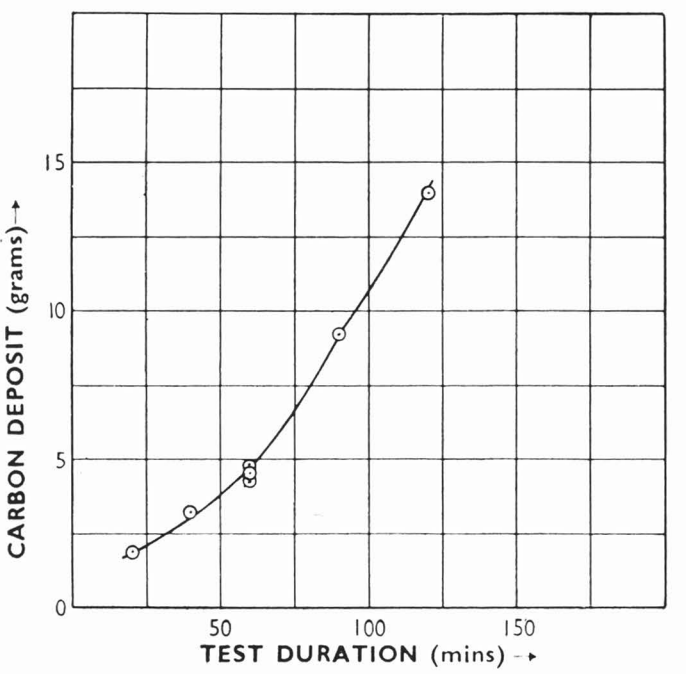

Fig. 13.—Effect of test duration on carbon deposits

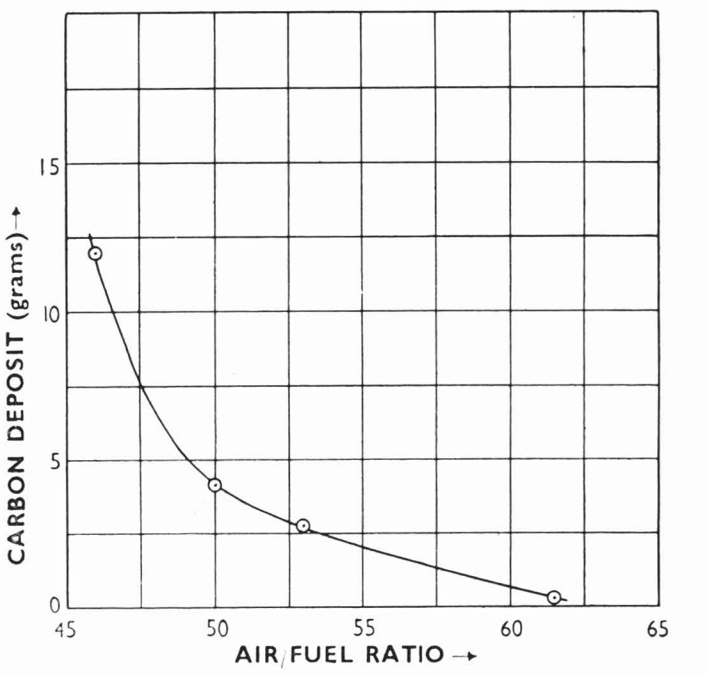

Fig. 14.—Effect of air/fuel ratio on carbon deposits

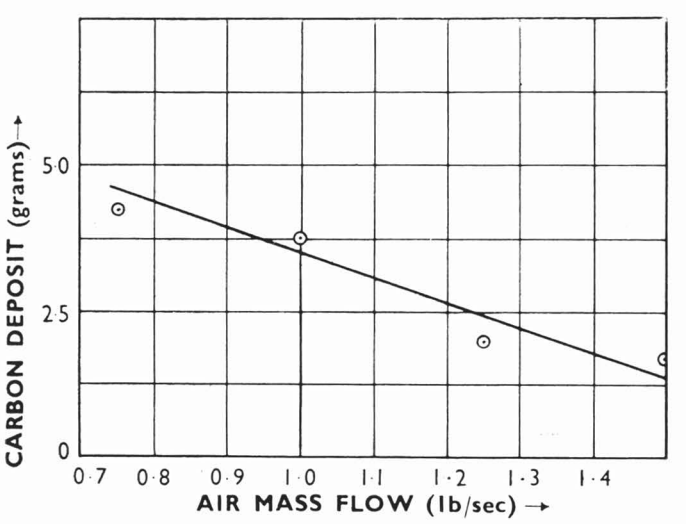

Fig. 15.—Effect of air mass flow on carbon deposits

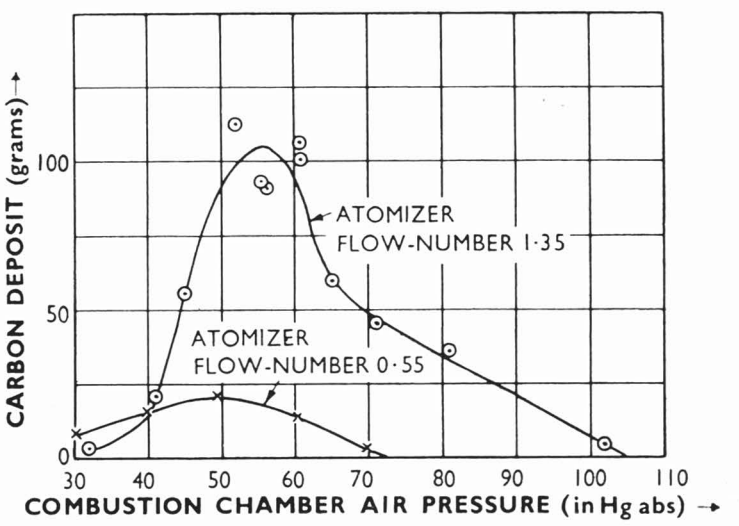

Fig. 16.—Effect of pressure and atomizer flow number on deposits

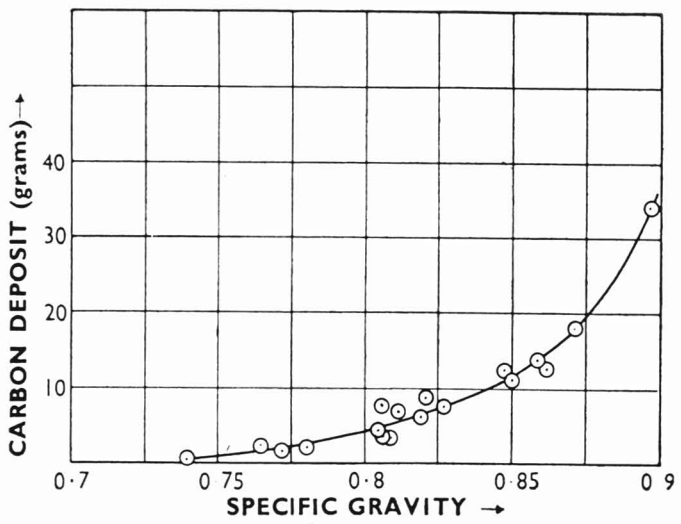

Fig. 17.—Effect of fuel specific gravity on carbon deposition

are built up round the circumference of the flame-tube wall in the region where fuel from the spray apparently reaches it. Deposits in the dilution zone are usually heavier, much thicker and softer than elsewhere, and either patchy or uniform round the circumference, depending on the flame pattern. These deposits can be far more troublesome than those in the combustion zone because of the large temperature gradients which can be created in the flame-tube material, leading to buckling and consequent cracking and loss of performance.

FIGS. 13-16 illustrate how various parameters (air flow, air pressure, time, fuel atomization, mixture strength) can influence the amount of carbon deposited in a given combustion chamber.

Most contemporary chambers do not now experience serious trouble due to carbon, and where such trouble does arise it can usually be largely eliminated by relatively minor design changes or innovations. However, there is always a possibility that in future engines more stringent demands on combustion chambers and the use of other fuels may result in a recurrence of the carbon deposition trouble in some degree, and a knowledge of the relative carbon-depositing tendencies of different fuels would then be of some help. It has not been found possible, despite the wide range of fuels investigated, to assess satisfactorily the relative importance of the separate effects of fuel features such as distillation characteristics, viscosity, chemical structure, carbon/hydrogen ration etc., but it has been found (at least for spray-type combustion chambers) that specific gravity can be used to estimate fuel performance in this respect sufficiently accurately for most practical purposes. TABLE II gives relevant fuel data and relative carbon depositions for various fuels which have been plotted against specific gravity in FIG. 17 and against carbon/hydrogen ratio in FIG. 18. FIG. 17 shows that fuel specific gravity satisfactorily summarizes the effect of all other fuel characteristics for the range of fuels covered.

Although no satisfactory detailed quantitative correlation of carbon depositing tendency with fuel characteristics has been achieved, FIG. 18 nevertheless illustrates the definite influence of carbon/hydrogen ratio—i.e. the higher the carbon/hydrogen ratio, the greater the relative tendency to deposit carbon. It will be noted however, that several points lie off the main curve at the lower end, and these belong largely to fuels which differ considerably in boiling or chemical characteristics from those associated with points on or near the curve.

With regard to the effect on carbon deposition of the fuel sulphur content, evidence has indicated that this has practically no effect even in concentrations as high as 1 per cent w. Gum content also appears to have no effect.

Evidence regarding carbon deposition in vaporizing-type chambers is relatively scanty but sufficient to indicate that this will be no more serious than in spray types.

TABLE II

Fuel Data and Relative Carbon Deposition Tendencies

Fuel	A.S.T.M. Distillation (° C.) I.B.P.	10%	50%	90%	F.B.P.	C/H Ratio	S.G. at 60° F.	Viscosity at 100° F. (cs)	Aromatics (% w)	Gum content (mg/100 ml)	Relative Carbon Deposition
Aviation kerosine	159	174	213	254	276	6·01	0·805	1·52	8·6	—	3·7
Vaporizing oil	143	161	197	241	262	6·43	0·821	1·23	21·9	41	8·5
Experimental kerosine	188	198	212	233	249	6·06	0·809	1·62	15·4	5	3·6
Diesel fuel	186	200	220	259	279	6·35	0·828	1·77	20·5	—	6·8
Diesel fuel	191	202	227	262	288	6·75	0·862	2·05	28·8	97	12·3
Hydrogenated creosote	188	206	222	264	309	6·85	0·871	1·93	23·0	—	18·0
American JP2 type	87	112	163	215	236	5·90	0·781	0·87	10·6	5	1·4
Hydrogenated gas oil	184	203	233	273	297	6·00	0·819	2·12	4·4	—	5·7
American JP2 type	59	89	152	242	266	5·81	0·764	1·14	16·1	3	2·1
Typical cracked wax	34	51	73	95	106	6·77	0·695	0·40	—	—	0·6
Typical cracked wax	52	93	206	290	315	6·62	0·771	1·10	—	—	1·2
Gas oil (sulphur content 0·64% w)	194	234	277	340	371	6·65	0·851	3·55	22·1	—	11·0
Hydrofined gas oil (as above) (sulphur content 0·15%)	204	232	275	355	378	6·42	0·848	4·22	22·6	—	12·0
Cracked gas oil (*98% at 371° C.)	195	235	265	319	*	7·35	0·896	3·93	—	—	34·4
Lye-treated cracked naphtha	68	105	143	190	211	6·59	0·803	0·88	—	54	4·2
Mixed octylenes	97	104	108	112	124	5·92	0·738	0·64	—	944	0
50% Lye-treated cracked naphtha / 50% vaporizing oil	88	128	174	227	260	6·51	0·812	2·3	—	48	6·1
18% mixed octylenes/82% vaporizing oil (equal concentrations of aromatics and unsaturates)	118	137	189	239	268	6·34	0·807	2·3	—	204	6·9
Pool gas oil	199	240	290	369	—	6·75	0·859	4·5	20·2	—	13·9

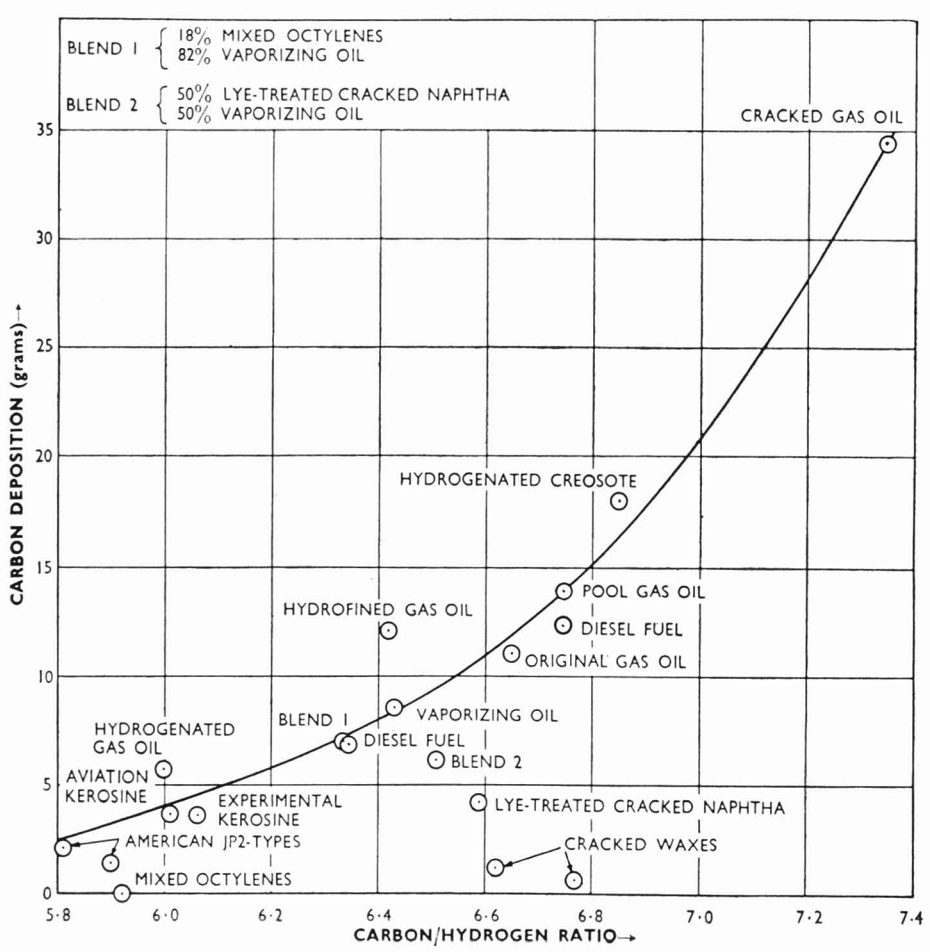

Fig. 18.—Effect of fuel carbon/hydrogen ratio on carbon deposition

Engine Supply Problems

The problems associated with supplying fuel from the aircraft tanks to the engine combustion chambers can be quite severe because of the wide range of air pressure and temperature under which modern aircraft are frequently required to operate. The fuel requirements can broadly be summarized as follows:

(*a*) Pumpability,
(*b*) freedom from filter clogging,
(*c*) low vapour (weathering) losses,
(*d*) safety,
(*e*) adequate lubricating and anti-corrosion properties,
(*f*) calorific value.

Dealing with these in detail:

(*a*) *Pumpability*

This is the requirement that the fuel can be pumped in adequate quantities under all operating conditions likely to be met in practice.

The fuel viscosity limitation required at the fuel atomizers in order to allow good combustion performance will be far below 2,000 centistokes, which is the order of viscosity at which pumpability troubles may arise. It is considered that even with the heaviest fuel likely to be used, serious pumpability troubles due to viscosity need not occur.

(*b*) *Freedom from Filter Clogging*

(i) *Due to ice.* It has been shown that under normal handling conditions aviation fuels as delivered to aircraft are invariably and inevitably saturated with water. Subsequent cooling of the fuel results in precipitation of ice which will clog filters normally capable of passing particles of less than 20-30 microns diameter.

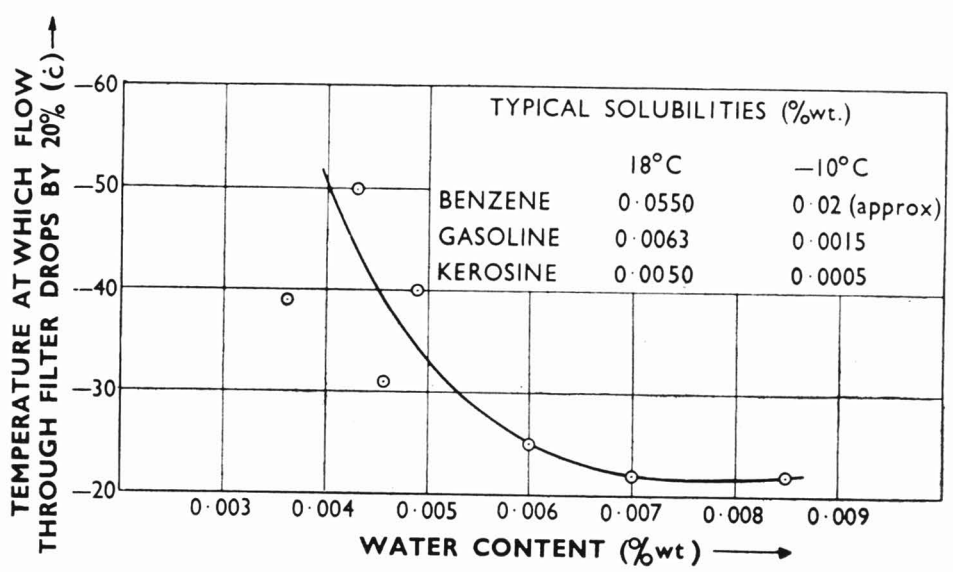

Fig. 19.—Effect of water solubility at 18°C on filter clogging due to ice

TABLE III

Fuel	Cloud Point (° C.)	Pour Point (° C.)	Temperature at which flow dropped by 20% of value calculated from extrapolated viscosity (° C.)
Gas Oil	− 7	−12	− 6
Kerogasoil	−45	−46	−43
Kerosine	−43	−54	−46
Diesel Fuel	−49	−54	−52
Vaporizing Oil	< −60	< −60	−60

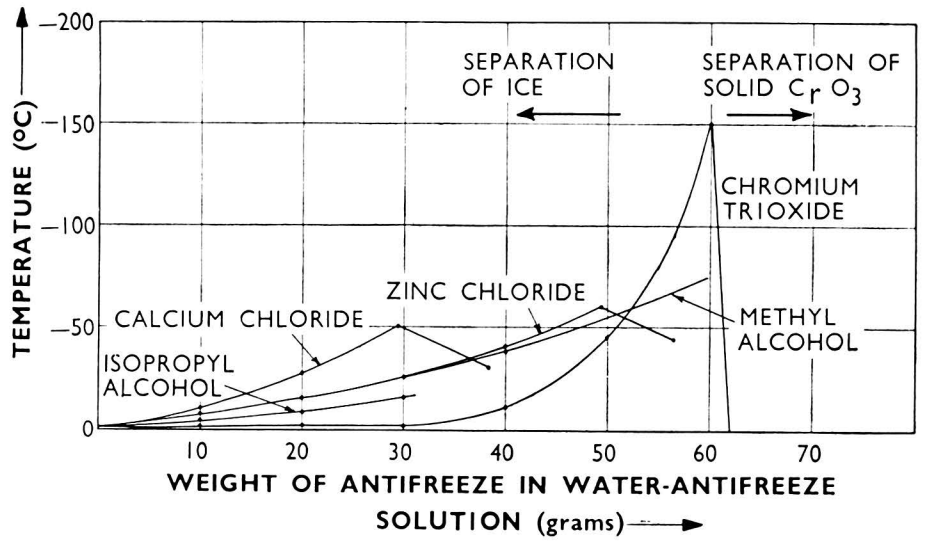

Fig. 20.—Solubility/freezing-point data for solutions of some proposed anti-freeze materials in water

It is possible under some conditions for the ice to form and sink to the bottom of the fuel tanks where it can do no harm, but on the other hand, some conditions can arise which allow the ice to pass into the fuel system and cause trouble.

Obviously the proneness of a fuel to filter clogging will depend on its water content, and a rough relationship between clogging tendency and water content exists, as shown in FIG. 19, in which typical solubility figures are given for three fuels.

Filter clogging by ice can be alleviated to some extent by using metal filters of the composite gauze or porous bronze type, instead of felt filters, which clog much more easily. This is because the rough barbed felt fibres permit a finite residence time even for a very small particle, the result being that whereas small particles of rust, for example, pass relatively easily through the felt pads, ice-crystals of similar size coalesce, and progressive blocking of the filter occurs.

Clearly the best solution of this problem lies in preventing the ice-crystals being precipitated, and various methods of achieving this have been tried. The general method of attack has been to introduce an 'antifreeze' into the fuel in liquid or solid form so that any water which separates out of solution with the fuel will contain a high proportion of antifreeze and so have a freezing point below the lowest fuel temperatures likely to be met in practice.

With regard to liquid antifreezing agents, the addition of iso-propyl alcohol or methyl-alcohol to the fuel in quantities of the order of 1 per cent of the fuel has been found successful in preventing ice precipitation down to temperatures lower than −50 deg. C. Unfortunately the high solubility of these alcohols in water leads to rapid depletion from fuel in contact with water, so that this method cannot be applied to fuels leaving a refinery, or even with safety to aircraft tanks. It is more effective to inject this type of antifreeze into the fuel system near the filter inlet when clogging begins.

Concerning the use of a solid antifreeze, one method is to place a gauze box containing the antifreeze in the fuel tank close to the fuel pump inlet. The antifreeze disperses through the fuel, and operates as does a liquid antifreeze.

In general this method is successful in preventing ice precipitation in the fuel, but brings further trouble connected with corrosion of fuel system and tank materials, and the quantities of antifreeze required. Further investigations concerning the best material to use are in progress. FIG. 20 gives curves showing the antifreeze performance of various materials which have been tried.

(ii) *Due to wax formation.* Although filter clogging by ice may eventually be overcome, that due to wax precipitation at low temperatures may still occur. TABLE III shows that there is a rough connexion between the cloud point of fuels and the temperature at which flow through the filter drops by 20 per cent. It is clear that the conventional cloud point can be used to indicate the temperature at which serious filter clogging trouble due to wax may occur.

(c) *Evaporation losses and vapour lock*

Increasing demands for gas turbine fuel may necessitate the use of more volatile types, introducing problems of fuel losses from the tank and vapour locking in the fuel system due to the rapid evolution of fuel vapour consequent upon the reduced barometric pressures encountered.

Vapour locking can to some extent be prevented by the use of booster pumps situated in the fuel tanks, but with high vapour pressure fuels even this method fails at high rates of climb and at altitude over about 40,000 ft. due to evolution of vapour even from fuel which has passed through the booster pump.

Vapour locking and evaporation losses can of course be prevented by the use of pressurized fuel tanks, but this is not always possible, and in any event may exact an appreciable weight penalty.

The evaporation characteristics of a fuel are determined by three main factors—the degree of self-cooling due to evaporation, the vapour pressure, and the vapour pressure change accompanying the loss of some of the lighter fuel fractions. Self-cooling is dependent on the fuel latent and specific heats, which do not vary very much for hydrocarbon fuels of particular types, although the self-cooling of paraffins can be increased to some slight extent by the introduction of such constitutents as aromatics or alcohols. The change in vapour pressure is, however, a very variable factor, since obviously a pure fuel will give no such change, whereas one composed of a very volatile and a non-volatile component will give a large change of vapour pressure for a given proportion lost as vapour.

Clearly, for a given vapour pressure, the fuel having the greatest fall in vapour pressure for a given degree of evaporation will give the smallest loss. Evaporation losses can be reduced by using a lower vapour pressure fuel, since firstly, the altitude at which boiling can occur is higher for a given fuel temperature, and secondly, the proportion of fuel lost for a given vapour pressure change is smaller.

In practice the fuel losses incurred by aircraft with vented tanks are determined by factors in addition to the evaporation characteristics of the fuel itself. For example, fuel cooling by conduction is a factor which is helpful but variable as it will alter with the type of aircraft and the rate of climb—a fast climb to a given altitude might entail an appreciable fuel loss—a slow one might incur negligible loss. Also, if the tank vents are small, losses may be kept small, although this may entail a tank pressure in excess of atmospheric by several pounds per square inch, and it is in effect a measure of pressurization.

It is apparent then, from evaporation loss and vapour locking viewpoints, that a low vapour pressure fuel such as kerosine is desirable for reducing these troubles. Employment of volatile fuel would logically mean the widespread use of precautions against fuel loss, i.e. tank pressurization, otherwise the increased evaporation losses resulting from the higher vapour pressure might largely offset the increased availability or reduced cost.

(d) *Safety*

The fires which following crash landings are perhaps the greatest dangers of aviation. These fires usually originate from (i) the ignition of the air/vapour mixture above spilled fuel by a spark or flame, and (ii) the spontaneous ignition of fuel or lubricating oil on a hot surface.

Tests have shown that for (i), fuel vapour pressure is the important factor. This can be related to its flash point and 10 per cent distillation temperature, so that any one of these three properties can be used to indicate the relative tendencies of fuels to ignite in this way. Flash points of typical fuels and oils are given in TABLE IV.

In connection with (ii) tests have been carried out which consisted, briefly, of dropping fuel on to a heated plate and measuring the minimum plate temperature at which spontaneous ignition of the fuel occurred. Typical spontaneous ignition temperatures obtained were as shown in TABLE IV.

It is clear from the results in TABLE IV, which are representative of many others, that for (i) aviation gasoline gives the greatest fire hazard, whereas lubricating oils give practically no danger and low volatility fuels are much safer than aviation gasoline. For (ii) lubricating oils are the most dangerous, and low volatility fuels are slightly more dangerous than aviation gasolines.

It should be remembered, however, that in practice a pilot will normally, if able, shut off the engine fuel supply if a crash is imminent, and considerable air cooling of engine components will occur. In many cases therefore gas-turbine engine components will not be sufficiently hot to ignite spontaneously fuels as heavy even as gas oil. The origin of crash fires is therefore, on balance, considered more likely to be (i) than (ii).

Once a fire has started, fuel vapour in its vicinity will ignite if the air/vapour mixture is within inflammability limits. Spilt gasolines at normal temperatures usually give inflammable mixtures whereas low volatility fuels do not until heat has been applied to raise the temperature of the fuel and its surroundings sufficiently. The time taken to do this will be of vital importance in the rescue of passengers in a crashed aircraft. Such fuels consequently possess an advantage over gasolines in this respect except possibly under tropical conditions.

It appears, therefore, from the crash landing viewpoint, that fuels of low volatility such as aviation kerosine are relatively safer than the lighter fuels because in addition to being less readily ignited under crash conditions, the chances of a fire spreading and rapidly enveloping the aircraft are considerably lessened by their use.

TABLE IV

Flash Points and Spontaneous Ignition Temperatures

Vapour Press. at 20° C. (mm)	Fuel or Oil	Flash Point ° C.	Spontaneous Ignition Temp. (° C.)	A.S.T.M. Distillation ° C. I.B.P.	50%	F.B.P.
184	Aviation gasoline	−40·0	725	42	96	169
3·3	Vaporizing Oil	38·3	520	143	197	262
2·2	RDE/SF/1 (low volatility gasoline)	38·3	625	161	180	202
1·6	RDE/SF/4 (low volatility gasoline)	40·0	720	164	178	196
1·8	Aviation kerosine	46·1	650	158	212	275
0·5	Hydrogenated gas oil	67·8	595	184	233	297
—	Typical lubricating oil	155·0	370	—	—	—

Lubrication and non-corrosivity

Efforts to obtain improved fuel atomization over a wide flow range have led to the use of very high fuel pressures (of the order of 700 lb./sq. in. upwards) under some conditions. This has resulted in high fuel-pump loadings and seizures have occurred particularly when using light fuels.

It has been found that the addition of 1 per cent or 2 per cent of lubricating oil to the fuel can have a beneficial effect where this trouble occurs. Owing to improvements in pump design, instances of seizures are much less frequent than formerly, and are now relatively scarce for fuels of the kerosine grades.

With regard to corrosion, this has occurred only with some experimental fuels, the attack being mainly on copper components of the fuel system. Provided that the neutralization value is maintained at the present specification figure of 0·1 mg KOH/g, little trouble should be experienced from this source.

Calorific Value

Since aircraft gas-turbines suffer from the drawback of high specific fuel consumption relative to piston engines, it is clear that the question of fuel calorific value is of some importance, and should be weighed carefully when considering possible fuels.

The different uses to which aircraft are put has a bearing on this question. For example, if tankage space is limited, as in fighter aircraft, range depends on fuel calorific value reckoned on a volume basis, whereas for a freighter where payload is important, range depends on the heat content per unit weight.

It has been found that for most hydrocarbon fuels calorific value can be related to specific gravity as shown in FIG. 21. In general the heaviest fuels have the highest bulk calorific values and the smallest gravimetric values, and vice-versa. The wide-cut fuels of the JP2 and JP3 types have, in general, rather low bulk calorific values due to the light fractions in their composition.

Since design trends appear on the whole to be towards aircraft (both military and civil) with volume-limited as against weight-limited fuel capacity, it would appear desirable to use the heaviest fuel consistent with other limitations. Such a fuel would normally have in addition the merit of low vapour pressure.

Availability

It has been shown that, practically, there is little to choose between likely fuels in regard to gas-turbine combustion performance, so this factor can be neglected when considering fuel availability.

Fuels of high vapour pressure, such as the gasolines, have advantages of low sulphur content, adequate-low-temperature properties and reduced tank explosion risks under certain conditions. On the other hand low vapour pressure fuels such as the kerosines have advantages of reduced evaporation loss and vapour lock troubles, higher volumetric heat contents, and in particular, greater safety characteristics under crash conditions which, it is felt, outweigh the advantages of the high vapour pressure fuels.

TABLE V gives details of a fuel conforming to the present specification (DERD.2482) for kerosine supplied for turbine engined aircraft. Due primarily to the restrictions on flash point and low-temperature properties the proportion of crude available as this type of fuel is relatively small.

It is theoretically possible to increase the amount of kerosine available by cracking materials to kerosine-type rather than gasoline-type products. The potential increase of yield by this method would, however, be relatively small and uneconomical. No satisfactory method for raising kerosine production to a high level appears to exist as yet.

It will be possible, however, to maintain a kerosine output sufficient to supply the needs of civil air transport for some time to come. This will allow the very desirable advantages of range and safety to be retained.

A wide-cut, high vapour pressure fuel conforming to the U.S. Specification AN-F-58a (an example is shown in TABLE V) can be produced in amounts representing large fractions of the crude. This latter fuel would, however, include a proportion of the motor gasoline stocks as well as the kerosines, and would encroach slightly on the gas oil range. Account must be taken of the demands for these products when making a true assessment of practical availability.

A compromise is possible by using a wide-cut fuel of, say, 1 lb./sq. in. rather than the 7 lb./sq. in. Reid Vapour Pressure of the AN-F-58a type. This would have the advantage of very much reduced evaporation loss and vapour lock troubles. The components not included in the compromise fuel would, of course, be available for use in other products, and it should be emphasized that the reduction in availability would not be as important as it appears, since the excluded components would be the more volatile fractions required for motor gasolines which, without tank pressurization, would be wastefully boiled off at altitude with consequent loss of range.

TABLE V

Properties of fuels conforming to specifications D/ENG.RD.2482 and AN.F.58a

Item	D/ENG.RD.2482		AN-F-58a	
	Fuel	Specification	Fuel	Specification
Reid Vapour Pressure at 100° F. (lb./sq. in.)	—	Not specified, but limited to a low figure by flash point specification	7	5 min. 7 max.
Flash point (Abel) (° F.)	100	100 min.	—	Not specified, but low value allowed by virtue of H.V.P. specification
Calorific Value (B.T.U./lb.)	18,700	18,300 min.		18,400 min.
S.G. 60/60° F.	0·795	Not restricted	0·778	0·728 to 0·802
Aromatic content (% vol.)	14	20 max.	30	30 max.
Sulphur content (% w)	0·08	0·1 max.	0·10	0·5 max.
Kinematic Viscosity (centistokes)	4·0 at 0° F.	6·0 max. at 0° F.	2·45 at −40° C.	10 max. at −40° C.
Freezing point (° C.)	−40	−40 max.	−60	−60 max.
A.S.T.M. Distillation (° C.):				
I.B.P.	150	Not restricted	38	Not restricted
10%	166	,,	75	,,
20%	173	200 max.	91	,,
50%	202	Not restricted	141	,,
90%	257	,,	258	204·4 min.

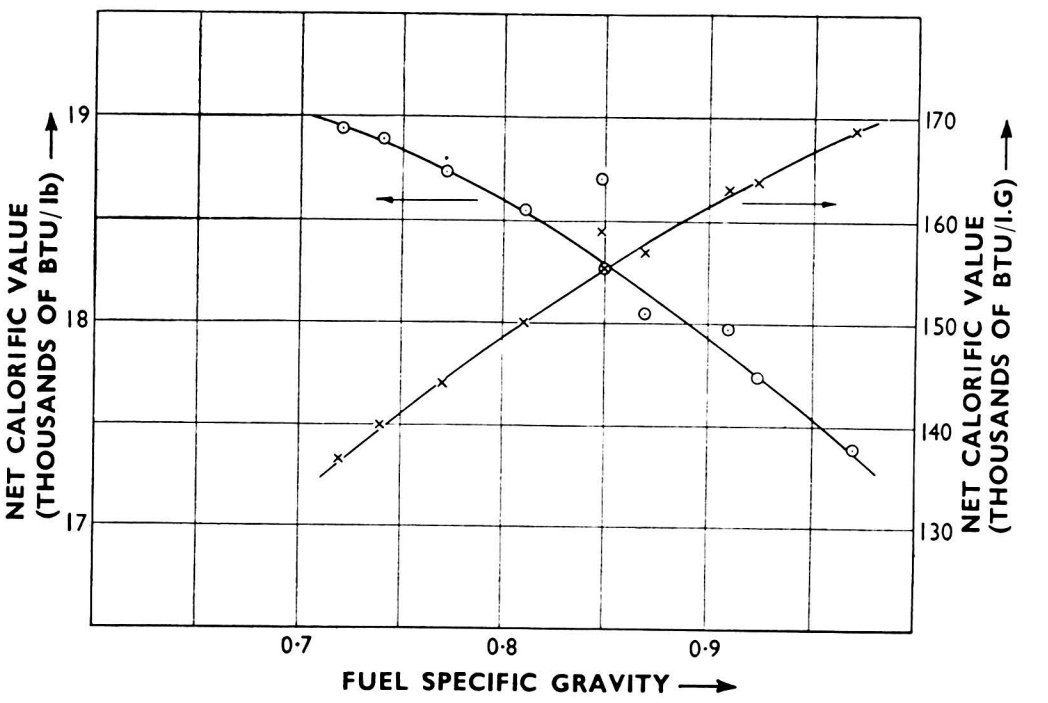

Fig. 21.—Net calorific values versus specific gravity (practical fuels)

ACKNOWLEDGMENT

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* 'Fuels and Lubricants for Aero Gas Turbines', by Dr C. G. Williams, *Journal of the Institute of Petrolem*, May 1947.

A.R.B. NOTICES

Civil Aircraft Inspection Procedures

The Council of the Air Registration Board announces the issue of the following:

Contents List, Issue 2
BL/6-7 'Synthetic Resin Adhesives.'
PL/3-1 'Propeller De-Icing—Fluid Method.'
EEL/3-1 'Installation and Maintenance of Electrical Cables.'
EEL/4-1 'Circuit Testing.'
ML/3-2 'Rigid Pipes.'
ML/3-3 'Tanks.'

Leaflet ML/3-1. Since the publication of Leaflet ML/3-1, tests have shown that flexible pipes are unlikely to be affected by momentary exposure to methyl bromide. Although the hose may be unsuitable if the lining is in continuous contact with methyl bromide, the purport of the note after paragraph 4.7 of the leaflet is not altered and, in the circumstances, it should be deleted. The leaflet will be amended in due course.

BOOKS RECEIVED

Metals at High Temperatures. By F. H. Clark. 372 pages, illustrated. [Chapman & Hall. 56*s*.]

Handbook of Experimental Stress Analysis. Edited by M. Hetényi. 1,077 pages, illustrated. [Chapman & Hall. 120*s*.]

Aeronautical Papers, 1885-1945, of Albert F. Zahm. 1,004 pages, illustrated. [University Press, Notre Dame, Indiana, U.S.A. $15.]

Moment of Resistance of Beams Stressed Beyond the Elastic Limit

An Accurate Method of Prediction which Applies to All Types of Sections and Materials having Different Stress-Strain Properties in Tension and Compression

By M. Ish Horowicz, M.Sc.(Tech.), Ing.(C.E.)

INTRODUCTION

MOST previous methods for predicting moments of resistance of beams subjected to pure bending beyond the limit of proportionality involve somewhat complicated and cumbersome calculations and are usually confined to specific materials and cross-sections.

Cozzone[14] has developed a method which applies only to sections symmetrical with respect to the axis of bending and materials having the same stress-strain curves in tension and compression[7].

Wolford's[43] formula ignores the curvilinearity of the stress-strain function and has actually been proposed for hollow sections only.

The analytical methods of Beilschmidt[5,6], Osgood[31, 32, 33], Gill[19], Vivian[40, 41], and other investigators imply the use of stress-strain approximations, the disadvantages of which are discussed in Section II of this paper.

The method proposed here applies to all types of sections and for materials having different stress-strain properties in tension and compression. The calculations are accurate and they involve very simple mathematical operations.

I. STATEMENT OF THE PROBLEM

The prediction of the behaviour in pure bending of beams stressed beyond the limit of proportionality of the material is based on the assumption that

(1) initially plane transverse sections remain plane after deformation;
(2) the stress-strain curves obtained in pure tension and compression are valid also in bending.

It follows from these assumptions that the stress distribution across the cross-section follows the stress-strain law in tension and compression.

The moments and stresses involved are calculated from the following requirements of equilibrium:

(*a*) The resultant of the normal stresses acting across any transverse section of the beam vanishes, i.e.

$$0=\int_0^A \sigma dA=\int_{h_c}^{h_t} \sigma b dx=R\int_{\epsilon_{ec}}^{\epsilon_{et}} f(\epsilon)b d\epsilon. \quad \ldots\ldots (1)$$

(*b*) The moment of the normal stresses is equal to the external applied bending moment at the section, i.e.

$$M=\int_0^A \sigma\, x\, dA=\int_{h_c}^{h_t} \sigma x b dx$$
$$=R^2\int_{\epsilon_{et}}^{\epsilon_{et}} b\, f(\epsilon)\epsilon\, d\epsilon \quad \ldots\ldots (2)$$

II. STRESS-STRAIN FUNCTIONS

Many types of approximations to the stress-strain curve of the material have been advanced to facilitate the evaluation of Moments of Resistance of cross-sections by the use of Equ. (2). They can be divided into two groups:

(1) Analytical stress-strain formulae as listed in TABLE I.
(2) Approximations to the stress-strain function by means of straight lines, as given in TABLE II.

A. Mathematical formulae (Table I)

It must be remembered that all the mathematical approximations have no theoretical background. The aim is to obtain a close fit between the suggested mathematical expression and the experimental curve irrespective of the physical laws governing the deformation. It is, of course, too much to expect that a single analytical equation will give a close fit to stress-strain curves of all materials.

In considering an analytical approximation the following points should be noted:

(1) *To what extent can the proposed curve approximate to the actual one.*
(*a*) Almost none of the tabulated expressions shows the point of inflection observed in many stones and in conventional stress-strain functions of ductile materials in compression.
(*b*) Hooke's formula 1 applies within the range of proportionality only.
(*c*) The potential curves 2, 3 and 6 start perpendicular to the strain axis and do not reflect the true modulus of elasticity.
(*d*) Only two potential expressions 4 and 5 provide factors for low strains corresponding to the linear part of the stress-strain curve.
(*e*) No materials except some cast irons exhibit a property of possessing a continuous stress-strain curve for tension and compression without any points of inflection, the parameters remaining constant throughout, as suggested by Vivian,[40, 41] for the formula 7 and by Bredt[10] for the expression 11*a*.
(*f*) The hyperbolic formula 24 will only apply to materials whose stress-strain curve is concave upwards and cannot be used for any metal or building material in which $\frac{d\sigma}{d\epsilon}$ decreases with rising stress.

(2) *Do simple methods exist to evaluate the parameters of the expressions, and what are they*?

Osgood[34] has described graphical methods of finding out the parameters of the potential

NOTATION

x=Distance of a fibre from the Neutral Axis.
b=Width of the transverse section at the distance x from the Neutral Axis.
h_t, h_c=Distance of the tensile, compressive extreme fibre from the Neutral Axis, respectively.
h=Total depth of the transverse section.
A=Area of the cross section.
σ=Stress.
ϵ=Strain.
$\sigma=f(\epsilon)$=Stress-strain function.
E=Young's Modulus of Elasticity.
σ_e, ϵ_e=Extreme fibre stress and strain, respectively.
t, c (as subscripts)=tensile and compressive, respectively.
σ_{et}, ϵ_{ec}=Extreme tensile and compressive fibre strains, respectively.
σ_y, ϵ_y=Stress and strain at the (lower) yield point.
σ_y^u=Upper yield point.
$U=\int f(\epsilon)d\epsilon$=Area of the stress-strain diagram enclosed by the strain axis, the curve and the strain co-ordinate parallel to the stress axis.
$Q=\int f(\epsilon)\epsilon d\epsilon$=First moment of the area U about the stress axis.
$R=\frac{h}{\epsilon_{et}+\epsilon_{ec}}$=Radius of curvature.
M=Bending Moment; Moment of Resistance.

Abbreviations

N.A.=Neutral Axis.
B.M.=Bending Moment.
M.R.=Moment of Resistance.
Equ.=Equation.
C.L.=Centroidal line parallel to the *N.A.*

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function 2 (applicable also to the exponential formulae 18*a* and 21), and of the hyperbola 14 and the polynomial expressions 15 and 16.

In the polynomial functions '*n*' constants can be determined analytically by solving '*n*' simultaneous equations with '*n*' unknown for '*n*' pairs of values (σ, ϵ) obtained from experiment.

In general the following methods can be used for the evaluation of parameters:

(*a*) In expressions with only one parameter this constant can be found analytically or graphically by substituting values of the stress and strain for any one point on the stress-strain curve.

(*b*) By using the first three or four terms of the expanded series of the exponential and hyperbolic functions. For instance with regard to the formula 18*b*.

$$e^{\frac{a\epsilon}{(1+\epsilon)}} = 1+a\epsilon(1+\epsilon)^{-1}+\tfrac{1}{2}\left[a\epsilon(1+\epsilon)^{-1}\right]^2 + \tfrac{1}{6}\left[a\epsilon(1+\epsilon)^{-1}\right]^3 + \ldots .$$

hence

$$\frac{\sigma}{E}=\frac{1}{a}\left[e^{\frac{a\epsilon}{1+\epsilon}}-1\right]=\epsilon(1+\epsilon)^{-1}+\tfrac{1}{2}a\epsilon^2(1+\epsilon)^{-2}+\tfrac{1}{6}\epsilon^3(1+\epsilon)^{-3}a^2$$

being a quadratic equation in '*a*'.

(*c*) By comparing the slopes of the actual stresses-strain curve and of the approximation, when much simpler expressions can be sometimes obtained; for instance for the equation 18*b*

$$E=\frac{d\sigma}{d\epsilon}=e^{a\epsilon} \quad \text{hence } a=\frac{2,3\log E}{\epsilon} \text{ and}$$

the diagram of log E against ϵ gives the solution.

(*d*) When two parameters '*a*' and '*b*' are included and the formula written in the form $b=f(a)$ then they are given by the coordinates of the point of intersection of two curves of '*b*' plotted against various values '*a*' for two pairs of known values (σ_1, ϵ_1) and (σ_2, ϵ_2). In this case the unknown '*b*' can also be eliminated by dividing the two obtained equations by each other. A particular case of such an elimination refers to the equation 25 (or to the slope of the function 26), by utilizing two pairs of corresponding values (ϵ_1, σ_1) and (ϵ_2, $\sigma_2=2\sigma_1$) and the relationship $\sinh(\beta\sigma_2)=2\sinh(\beta\sigma_1)\cosh(\beta\sigma_1)$. The ratio obtained then is $\frac{\epsilon_2}{\epsilon_1}=2\cosh(\beta\sigma_1)$, from which '$\beta$' and later '*a*' can be determined.

It is obvious that the above methods involve generally elaborate calculations, and actually they should be also repeated for several pairs of values (σ, ϵ) taken from the curve obtained in tests.

TABLE I—STRESS-STRAIN FORMULAE

NOTATION: σ, ϵ = Stress and strain, respectively.
σ_p, ϵ_p = σ, ϵ at the limit of proportionality.
E = Young's Modulus.
e = 2·71828 (exponential *e*).
$J, a, b, c, d, k, m, \alpha, \beta, \gamma$ = Parameters.

No.	Type	Formula	Material	Remarks and (References)
1	LINEAR	$\sigma=E\epsilon$	Brittle materials, other materials in the elastic range	Hooke's Law
2a 2b	POTENTIAL	$\sigma=a\epsilon^k$ .. .. $\epsilon=a\sigma^\beta$	Cast iron, aluminium, copper, magnesium, light alloys, concrete, granite, marble, cement, leather	(1, 2, 5, 6, 10, 18, 19, 22)
3		$\sigma=a\epsilon^k-b\epsilon^2$	Cast iron, stones, etc.	(34, 38)
4		$\sigma=E\epsilon+b(\epsilon-\epsilon_p)^k$	Duralumin	For $\epsilon<\epsilon_p$, $b=0$ (21)
5		$\epsilon=a\sigma+\beta(\sigma-\sigma_p)^k$	.. ..	For $\sigma<\sigma_p$, b=0 (34)
6		$\epsilon=\frac{\sigma}{E}+b\left(\frac{\sigma}{E}\right)^k$	Light alloys	(31, 32, 33, 34)
7		$\sigma=\sigma_e\left[1-\left(1-\frac{\epsilon}{\epsilon_e}\right)^k\right]$	.. ..	(39)
8		$\sigma=\sigma_e\left[\left(\frac{\epsilon}{\epsilon_e}+1\right)^{J-1}-1\right]$ ..	Cast iron	(40, 41)
9	PARABOLA	$\epsilon=a\sigma+\beta\sigma^2$	Cement, mortar	(13, 23, 34)
10a		$\sigma=a\epsilon+b\epsilon^2$	Cast iron, steel	$b<0$ (34)
10b		$\sigma=a\epsilon-b\epsilon^2$		$b>0$ (12, 13, 34)
11a	HYPERBOLA	$\sigma=\frac{a\epsilon}{1+b\epsilon}$	Cast iron	$b>0$ (10, 13, 23)
11b		$\epsilon=\frac{\sigma}{a-b\sigma}$		$b>0$ (13, 23, 34)
12		$\epsilon^2=a\sigma^2+b\sigma$	Organic tissues	$a>0$ (23, 34)
13		$\sigma=a-\frac{b}{c+\epsilon}$	Magnesium alloys	(16)
14		$\sigma=\frac{E\epsilon(1+b\epsilon)}{1+a\epsilon}$	.. ..	For large strains $a>0$, $b>0$ (34)
15	POLYNOMIAL	$\sigma=a\epsilon+b\epsilon^2+c\epsilon^3$	Cast iron, steel	(13, 23, 28, 34)
16		$\epsilon=a\sigma+\beta\sigma^2+\gamma\sigma^3$	Metals in tension	(23)
17		$\sigma=a\epsilon+b\epsilon^2+c\epsilon^3+d\epsilon^4$	Cast iron	(23, 34)

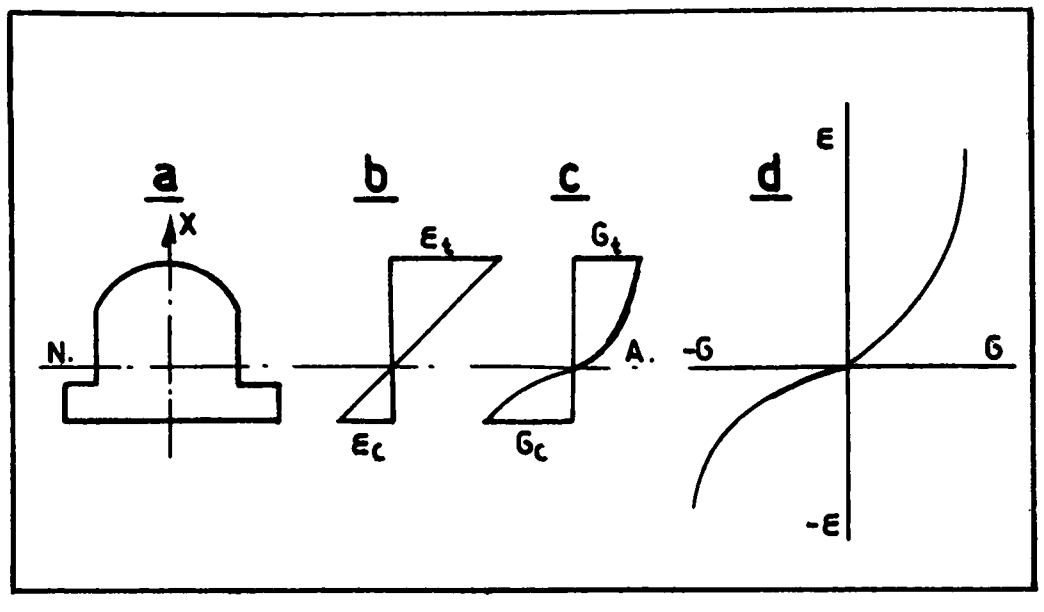


Fig. 1

(3) *Can the expressions proposed be integrated when substituted in equs.* (1) *and* (2) *for all type of cross-sections.*

The polynomial formulae seem to be the easiest for integration, the calculations involved are, however, cumbersome and the expressions obtained lengthy. The last disadvantage applies also to most of the potential formulae [2, 5, 6, 19, 31, 32], although the form 2 is probably the most convenient in use, so that practical engineers may feel disinclined to take advantage of the proposed methods involving preparationof numerous tables and graphs [19, 6]. The integration of all other formulae seems to be very difficult and cumbersome, and for beams other than of rectangular cross sections mostly impossible. This applies to hyperbolae 11-14 and most of the exponential and hyperbolic formulae.

The amount of work involved will be consider-

TABLE I (continued)

18a	EXPONENTIAL	$\sigma=ce^{1/\epsilon}$	.. ..	(23)
18b		$\sigma=\frac{E}{a}\left(e^{\frac{a\epsilon}{1+\epsilon}}-1\right)$	.. ..	(34)
19		$\sigma=\frac{E}{a}\left(e^{a\epsilon}-1\right)$	Leather in tension, burnt clay in compression	(23, 34)
20		$\epsilon=\frac{1}{m}\left(e^{m\sigma}-1\right)$	Caoutchouk	(34)
21		$\sigma=\frac{\epsilon}{1-\epsilon}e^{m\epsilon}$	Cork in compression	(23, 34)
22		$\epsilon=\frac{\sigma}{E}\left[1+\beta\left(e^{a\sigma/E}-1\right)\right]$ ..	Brass in tension	(23, 34)
23		$\epsilon=\frac{a\sigma}{E}+b\left(e^{\frac{1-a}{b}\frac{\sigma}{E}}-1\right)$ ..	.. ..	For large strains (34)
24	HYPERBOLIC	$\sigma=a\sinh\epsilon$	.. ..	(16)
25		$\epsilon=\alpha\sinh\beta\sigma$	.. ..	(21)
26		$\epsilon=\frac{\sigma}{E}+\beta\left[\cosh\alpha\frac{\sigma}{E}-1\right]$ ..	.. ..	(34)
27		$\frac{\sigma}{E}=a\epsilon+b\tanh\left[\frac{1-a}{b}\epsilon\right]$ ..	Light alloys, etc.	(36)

ably increased both in determining the parameters and performing the integrations when according to Beilschmidt's suggestion[5] the actual stress-strain curve will be replaced by a formula having different values of the parameters for each portion of this curve. The work is also increased where the material's stress-strain curve is different in tension and compression.

It will be seen later that the method proposed in this paper for evaluating the *M.R.* can use mathematical approximations for the stress-strain curves, and the integrations required are much simpler because they are independent of the shape of the cross-sections, i.e. of the term b in the equs. (1) and (2)

(4) *Can the formula* $\epsilon=g(\sigma)$ *be easily converted into the form* $\sigma=f(\epsilon)$, *and vice-versa to simplify any integrations.*

This is very simple with regard to the approximations 2, 11 and 13. In other cases such a conversion is either impossible (26, 27, generally 17, etc.) or quite impracticable.

B. Linear Approximations (Table II)

The linear approximations are much simpler in use. They save the work involved in the integrations and in the determination of the parameters, but their departure from the actual stress-strain function is much larger and the calculated *M.R.* is not as accurate.

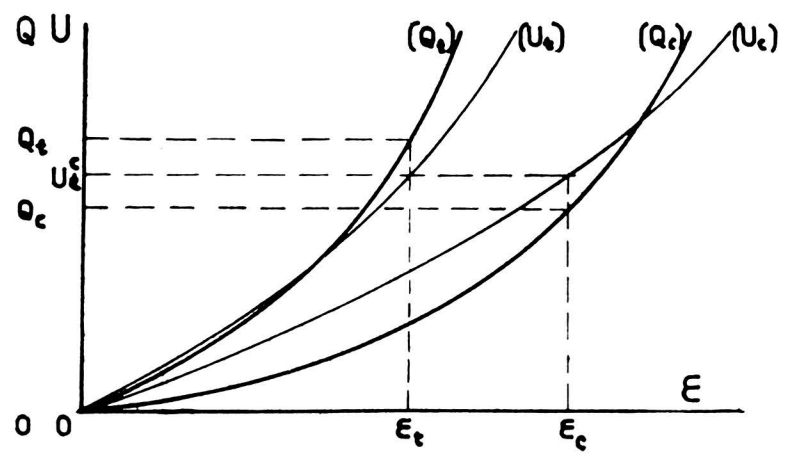


Fig. 2

III. PREDICTION OF THE M.R. OF CROSS-SECTIONS

The most accurate results are, of course, obtained when the actual stress-strain curve obtained in tension and compression tests is applied and not an approximation. Following the assumptions stated before for the predicting of *M.R.* of sections subjected to pure bending, because of the linear strain distribution, FIG. 1*b*, the stress distribution, FIG. 1*c*, across a transverse section, FIG. 1*a*, corresponds to the stress-strain curve, the stress axis of which coincides with the *N.A.* (FIG. 1*d*) Previously the actual stress-strain curve was applied to only reactangular sections [2, 24, 29], where since b is constant the equ. (1) can be written in the form

$$U_c=\int_0^{h_c} f(\epsilon)d\epsilon=\int_0^{h_t} f(\epsilon)d\epsilon=U_t \quad .. \quad (3)$$

The *M.R.* of the rectangular section is according to equ. (2)

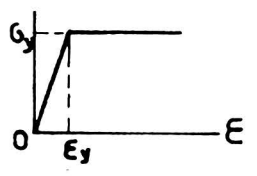
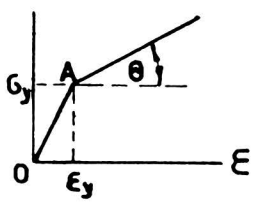
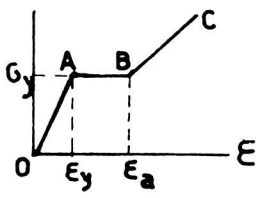
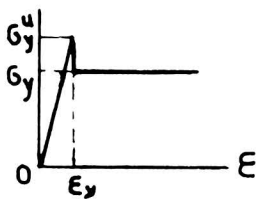
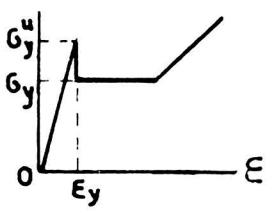
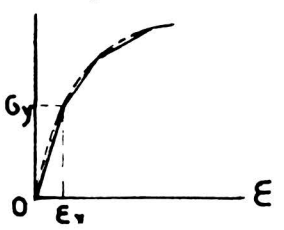
$$M=bR^2\left[\int_{\epsilon_{ec}}^{0} f(\epsilon)\epsilon d\epsilon+\int_0^{\epsilon_{et}} f(\epsilon)\epsilon d\epsilon\right]$$
$$=bR^2(Q_c+Q_t). \quad ..... \quad (4)$$

Cozzone[14] in his method has replaced the curvilinear stress distribution by means of a trapezoidal one, which while leaving the extreme fibre stress σ_t unaltered had the same first moment about the *N.A.* as that obtained from the actual curvilinear distribution. Accordingly the areas U and the first moments Q had to be determined first from the stress-strain function.

PROPOSED METHOD

The method proposed here applies also to unsymmetrical sections and materials having different stress-strain properties in tension and compression. The calculations involved are very simple and accurate.

TABLE II—LINEAR APPROXIMATIONS OF STRESS-STRAIN FUNCTIONS

No.	Stress-Strain Approximations	Materials	References
1		Ideally plastic materials, mild steel wrought iron	8, 15, 17, 26, 27, 30, 35, 37, 42.
2		Manganese steel, aluminium alloys, magnesium alloys, duralumin	11, 25, 29, 42
3		Mild steel, wrought iron	20, 35, 37
4		Mild steel, wrought iron	3, 4, 12, 26
5		Mild steel, wrought iron	3, 25, 36, 37
6		Materials with curvilinear stress-strain properties	21

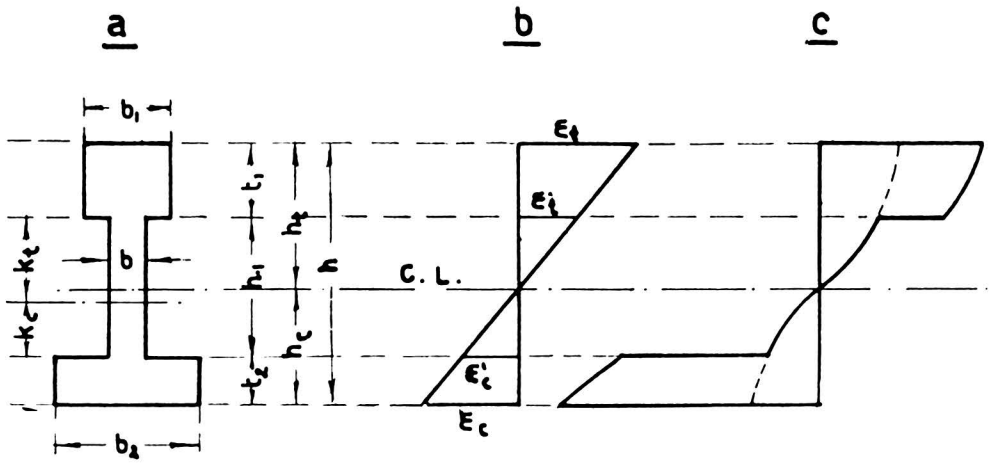


Fig. 3

From the stress-strain diagrams obtained in tests the following quantities are tabulated and plotted against, the strain ϵ as shown in FIG. 2 and e.g. TABLE III:

(*a*) Areas U of the stress-strain curve enclosed by the stress axis, the curve and the co-ordinates of the corresponding strains ϵ, in tension and compression.

(*b*) First moments Q of these areas U about the stress axis against the corresponding strains ϵ.

If the stress-strain function can be expressed by a mathematical approximation $\sigma=f(\epsilon)$, the curves

$$U=\int_0^{\epsilon} f(\epsilon)d\epsilon \text{ and } Q=\int_0^{\epsilon} f(\epsilon)\epsilon de \text{ for various}$$

values of ϵ can be calculated analytically.

The application of these two curves $U-\epsilon$ and $Q-\epsilon$ is described for sections enclosed by boundaries parallel and perpendicular to the plane of bending and made of materials possessing identical or different stress-strain characteristics in tension and compression as well as for sections enclosed by boundaries of any shape. For these latter a different graphical method is given, which can of course be used generally with respect to any transverse sections and materials.

A. Sections enclosed by boundaries parallel and perpendicular to the plane of bending

1. *Exact method*

The exact method entails rather cumbersome calculations. Considering for example the I section in FIG. 3*a* we obtain from equ. (1)

$$0=\int_{\epsilon_c}^{\epsilon_t} bf(\epsilon)d\epsilon=$$

$$=\frac{b_2}{b}\int_{\epsilon_c}^{\epsilon'_c} f(\epsilon)d\epsilon+\int_{\epsilon_c}^{0} f(\epsilon)d\epsilon$$

$$+\int_{0}^{\epsilon'_t} f(\epsilon)d\epsilon+\frac{b_1}{b}\int_{\epsilon'_t}^{\epsilon_t} f(\epsilon)d\epsilon$$

hence

$$\int_0^{\epsilon_t} dU+\frac{b_1}{b}$$

$$\left(\int_0^{\epsilon_t} dU-\int_0^{\epsilon_t} dU\right)$$

$$=\int_0^{\epsilon'_c} dU+\frac{b_2}{b}$$

$$\left(\int_0^{\epsilon_c} dU-\int_0^{\epsilon'_c} dU\right)$$

or

$$U'_t+\frac{b_1}{b}\left(U_t-U'_t\right)=U'_c+\frac{b_2}{b}\left(U_c-U'_c\right) \quad \ldots\ldots\ldots (5)$$

The strains ϵ_t, ϵ_t, ϵ'_c and ϵ_c to which the respective areas U'_t, U_t, U'_c and U_c correspond are calculated from FIGS. 3*a* and 3*b*, viz.:

$$\frac{\epsilon_t-\epsilon'_t}{\epsilon_c+\epsilon_t}=\frac{t_1}{h} \text{ and } \frac{\epsilon_c-\epsilon'_c}{\epsilon_c+\epsilon_t}=\frac{t_2}{h}$$

$$\left.\begin{aligned}\text{hence } \epsilon'_t&=\epsilon_t-\left(\epsilon_c+\epsilon_t\right)\frac{t_1}{h}\\ \text{and } \epsilon_c&=\epsilon_c-\left(\epsilon_c+\epsilon_t\right)\frac{t_2}{h}\end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (6)$$

in which for a certain tensile extreme fibre strain ϵ_t the values of ϵ_t, ϵ'_c and ϵ_c are unknown. These strains and the corresponding values of U'_t, U'_c and U_c can be determined only by trial, as follows:

A value for ϵ_c is assumed, the strains ϵ'_t and ϵ'_c calculated from equs. (6) and next the areas U_t, U_c, U'_t and U'_c obtained from the graphs in FIG. 2. If these values satisfy the equ. (5), the guess for ϵ_c was correct and then the $M.R.$ is calculated from the equation

$$M=R^2b\left[\int_0^{\epsilon'_t} f(\epsilon)\epsilon d\epsilon+\frac{b_1}{b}\int_{\epsilon'_t}^{\epsilon_t} f(\epsilon)\epsilon de\right.$$

$$\left.+\int_{\epsilon'_c}^{0} f(\epsilon)\epsilon d\epsilon+\frac{b_2}{b}\int_{\epsilon_c}^{\epsilon'_c} f(\epsilon)\epsilon d\epsilon\right]$$

i.e. $$M=\frac{bh^2}{(\epsilon_c+\epsilon_t)^2}\left[Q'_t+\frac{b_1}{b}(Q_t-Q'_t)\right.$$

$$\left.+Q'_c+\frac{b_2}{b}(Q_c-Q'_c)\right] \quad \ldots\ldots\ldots (7)$$

where the values of Q are obtained from the diagram in FIG. 2. If equ. (5) is not satisfied another value for the compressive extreme fibre strain, say, ϵ_{co}, should be assumed and the calculation repeated.

The difficulty consists of the impossibility of finding the values of $\int bdU$ and $\int bdQ$ before

TABLE III

Areas (U) and First Moments (Q) of the stress-strain curves of Duralumin ST.17

ϵ	$\Delta\epsilon$	COMPRESSION					TENSION				
10^{-4}	10^{-4}	σ ton/in.^{2}	$\Delta U=\sigma\Delta\epsilon$ 10^{-4} ton/in.^{2}	$U=\Sigma\Delta U$ 10^{-4} ton/in.^{2}	$\Delta Q=\eta\Delta U$ 10^{-8} ton/in.^{2}	$Q=\Sigma\Delta Q$ 10^{-8} ton/in.^{2}	σ ton/in.^{2}	$\Delta U=\sigma\Delta\epsilon$ 10^{-4} ton/in.^{2}	$U=\Sigma\Delta U$ 10^{-4} ton/in.^{2}	$\Delta Q=\eta\Delta U$ 10^{-8} ton/in.^{2}	$Q=\Sigma\Delta Q$ 10^{-8} ton/in.^{2}
0		0		0		0	0		0		0
	4·0		3·78		10·087			3·668		9·781	
4·0		1·89		3·78		10·087	1·834		3·668		9·781
	4·0		11·35		70·599			11·004		68·465	
8·0		3·78		15·13		80·682	3·668		14·672		78·246
	4·0		18·91		191·622			18·340		185·850	
12·0		5·67		34·04		272·304	5·502		33·012		264·096
	4·0		26·47		373·159			25·676		440·157	
16·0		7·56		60·51		645·463	7·336		58·688		626·007
	4·0		33·99		614·507			33·012		596·629	
20·0		9·45		94·50		1259·970	9·170		91·700		1222·636
	4·0		41·65		918·462			40·348		890·132	
24·0		11·34		136·15		2178·432	11·004		132·048		2112·768
	3·5		42·60		1098·648			41·326		1065·698	
27·5		13·00		178·75		3277·080	12·609		173·374		3178·466
	2·3		34·05		883·183			30·220		866·275	
29·8		14·00		209·80		4160·263	13·664		203·594		4044·741
	2·0		28·82		887·929			28·101		866·993	
31·8		14·82		238·62		5048·192	14·572		231·695		4911·734
	2·0		30·41		997·704			30·086		986·977	
33·8		15·59		269·03		6045·896	15·490		261·781		5898·711
	2·0		31·88		1109·657			31·922		1111·010	
35·8		16·29		300·91		7155·553	16·408		293·703		7009·721
	2·0		35·23		1223·080			33·758		1242·296	
37·8		16·94		334·14		8378·633	17·326		327·461		8252·017
	2·0		34·47		1337·632			35·595		1380·948	
39·8		17·53		368·61		9716·265	18·244		363·056		9632·965
	2·0		35·62		1453·482			37·430		1527·258	
41·8		18·09		404·23		11169·747	19·162		400·486		11160·223
	2·0		36·68		1570·070			39·288		1681·178	
43·8		18·59		440·91		12739·817	20·081		439·774		12841·401
	2·0		37·62		1685·523			41·126		1841·919	
45·8		19·03		478·53		14425·340	21·000		480·900		14683·320
	2·0		38·45		1799·590			42·515		1989·873	
47·8		19·42		516·98		16224·930	21·515		523·415		16673·193
	2·0		39·18		1912·097			43·270		2111·656	
49·8		19·76		556·16		18137·027	21·755		566·685		18784·849
	2·0		39·83		2023·467			43·655		2217·722	
51·8		20·07		595·99		20160·494	21·900		610·340		21002·571
	2·0		40·42		2134·269			43·930		2319·551	
53·8		20·35		636·41		22294·763	22·040		654·270		23322·122
	2·0		40·96		2244·695			44·220		2423·303	
55·8		20·61		677·37		24539·458	22·180		698·470		25745·425
	2·0		41·46		2355·008			44·500		2527·647	
57·8		20·85		718·83		26894·460	22·32		742·990		28273·072
	2·0		41·93		2465·561			44·780		2633·111	
59·8		21·08		760·76		29360·027	22·46		787·77		30906·183
	2·0		42·37		2576·166			45·100		2742·127	
61·8		21·29		803·13		31936·193	22·60		832·87		33648·310
	2·0		42·77		2673·459			45·340		2847·399	
63·8		21·48		845·90		34609·652	22·74		878·21		36495·709
	2·0		43·13		2794·881			45·610		2955·571	
65·8		21·65		889·03		37404·533	22·87		923·820		39451·280
	2·0		43·48		2902·510			45·870		2997·360	
67·8		21·80		932·51		40307·043	23·00		969·690		42448·640
	1·6		34·99		2400·481			36·836		2526·960	
69·4		21·94		967·50		42707·524	23·045		1005·520		44975·600
	7·4		163·80		11975·363			171·362		12520·028	
76·8		22·33		1131·60		54682·887	23·215		1176·788		57495·628
	7·5		168·94		13609·619			174·750		14076·869	
84·3		22·72		1300·24		68292·506	23·385		1351·538		71572·497
	6·2		141·73		12388·264						
90·5		23·00		1441·97		80680·770					

the position of the *N.A.* has been determined in accordance with the condition of equilibrium (1).

2. *Discussion on the Position of the Neutral Axis*

In order to avoid the troublesome calculations involved in the accurate method owing to continuous variations in the position of the *N.A.*, it is often assumed to coincide with the *C.L.* perpendicular to the plane of bending. Many investigators including Cozzone[14], Bollenrath and Schiedt[9], Cox[13] and others have assumed no *N.A.* shift.

The following discussion will justify such an assumption: Considering for instance a rectangular section, where $M=bR^2(Q_t+Q_c)$, and assuming the *N.A.* to pass through the centroid of the section the value of the *M.R.* will be $M'=bR^2(Q_t'+Q_c')$.

The error involved due to ignoring the shift of the *N.A.* is

$$\Delta M=M'-M=bR^2\left[(Q_t'-Q_t)-(Q_c-Q_c')\right] \quad \ldots\ldots (8)$$

Supposing now that for a given extreme fibre strain the shift of the *N.A.* from *C.L.* is towards the compressive flange, then $\epsilon_t'>\epsilon_t$ and $\epsilon_c'<\epsilon_c$, hence $Q_t'>Q_t$ and $Q_c'<Q_c$. Accordingly

$$\Delta Q_t=Q_t'-Q_t>0$$

and $\Delta Q_c=Q_c-Q_c'>0.$

Substituing these values into equ. (8)

$$\Delta M=bR^2(\Delta Q_t-\Delta Q_c),$$

where the term in the brackets is a difference of two positive quantities of the second order of magnitude. Hence the assumption that the *N.A.* passes through the centroid of the section involves an error of a very small order.

In non-reactangular sections the shift of the *N.A.* will be smaller for those in which the material is concentrated near the *N.A.* and larger for those in which it lies near the flanges. At the moment of failure it was found by Bach[2] to equal 8 per cent of the total depth of the cross-section. This amount depends, of course, upon the shape of the cross-section and the difference between the stress-strain diagrams in tension and compression. In practice the working extreme fibre strains are so small in comparison with their magnitude at fracture that neglecting the shift is completely reasonable and acceptable, whilst it saves a remarkable amount of complicated calculations and guesswork.

3. *Simplified Method*

Taking the *N.A.* to pass through the centroid of the cross-section the procedure now is simple. Considering for instance the I section in FIG. 3*a*

(*a*) for a given ϵ_t the values of ϵ_t, ϵ_c and ϵ_c can be calculated from linear strain distribution by applying equs. (6)

(*b*) for each of these values the magnitudes of the corresponding first moments Q_t, Q_t', Q_c' and Q_c are next found from the graphs in FIG. 2 and introduced into the equ. (7) for the moment, i.e.

$$M=\frac{bh^2}{(\epsilon_c+\epsilon_t)^2}\left[Q_t'+\frac{b_1}{b}(Q_t-Q_t')+Q_c'+\frac{b_2}{b}(Q_c-Q_c')\right]$$

The expression in the square brackets represents the first moment of the diagram given in FIG. 3*c* about the *C.L.*

In the case of a section symmetrical with respect to the axis of bending and a material possessing the same properties in tension and compression the *N.A.* does pass through the centroid, and for an I section $b_1=b_2$, $\epsilon_t=\epsilon_c$, $Q_t=Q_c$ and $Q_t'=Q_c'$, hence the equ. (7) can be written in the form

$$M=\frac{bh^2}{2\epsilon_t^2}\left[Q_t'+\frac{b_1}{b}(Q_t-Q_t')\right].$$

The advantages of the method demonstrated above as compared with Cozzone's trapezoidal system of calculations, which applies only to symmetrical sections and identical tensile and compressive stress-strain functions of the material, can be summarized as follows:

(*a*) The stress distribution corresponds to the actual stress strain curve and not to an approximate one. The results are therefore more accurate and the real state of stress represented.

(*b*) While the preliminary evaluation of the first moments '*Q*' is essential in both methods, the procedure proposed here does not require any additional calculations such as determination of the trapezoidal intercepts by equating the first moment of the trapezoidal distribution to the actual value of *Q*, finding the first moment of the cross-section, the section factor *k*, modulus of section, etc.

(*c*) No other curves are needed apart from those of the first moments $Q-\epsilon$.

It can be remarked that for rectangular transverse sections even when the stress-strain characteristics are different in tension and compression the accurate method of predicting the *M.R.* is simple. According to equ. (1) $U_c=U_t$ and from equ. (2)

$$M=\frac{bh^2}{(\epsilon_c+\epsilon_t)^2}(Q_c+Q_t) \quad \ldots\ldots (9)$$

Hence the procedure in calculation is as follows[29]:

For a given extreme fibre strain ϵ_t the corresponding values U_t and Q_t are found from the diagram in FIG. 2. The intersection of a line parallel to the ϵ axis through the point U_t with the (U_c) curve gives the point $U_c=U_t$ which determines the appropriate values of ϵ_c and Q_c to be substituted into the equ. (9) of *M*.

B. Sections with curved sides or straight but not parallel and perpendicular to the plane of bending

Circular and diamond sections represent these types of transverse sections. For reasons of simplicity the evaluations are made again with respect to the *C.L.* and the shift of the *N.A.* is ignored.

The method is based on the following expressions for the *M.R.* of the section from equ. (2)

$$M=R^2\int_{\epsilon_{ec}}^{\epsilon_{et}} b\sigma\epsilon d\epsilon=\frac{h^2}{(\epsilon_c+\epsilon_t)^2}$$

$$\int_{\epsilon_{ec}}^{\epsilon_{et}} bdQ=\frac{h^2}{(\epsilon_c+\epsilon_t)^2}\sum_{\epsilon=\epsilon_{ec}}^{\epsilon=\epsilon_{et}} b\Delta Q \quad \ldots. (10a)$$

and

$$M=\int_{h_c}^{h_t} \sigma bxdx=\sum_{x=h_c}^{x=h_t}\sigma bx\Delta x \quad \ldots. (10b)$$

(*a*) Assuming a linear strain distribution across the transverse sections for a certain extreme fibre strain ϵ_t the strains ϵ at various distances *x* from the *N.A.* including the value of ϵ_c in FIG. 3*b* can be calculated from the relationship

$$\frac{\epsilon}{\epsilon_t}=\frac{x}{h_t} \quad \ldots\ldots\ldots (11)$$

Now $\Delta Q=\sigma\epsilon d\epsilon=Q'-Q''$,
where Q' and Q'' are the values of Q for $\epsilon=\epsilon'$ and $\epsilon=\epsilon''$, ϵ' and ϵ'' being the strains at the top and bottom of an elementary strip of the stress-strain diagram; hence ΔQ can be determined from the $Q-\epsilon$ tabl s (TABLE III) or curves (FIG. 2). It may be easier first to assume various values of $\epsilon'_t, \epsilon''_t, \ldots \epsilon'''_c, \epsilon''_c \ldots$ and to calculate from equ. (11) the corresponding distances *x* for the boundaries of the elementary strips, and then to determine the values of ΔQ. These values are next multiplied by the mean width b_m of the corresponding strip of the transverse section. The products $(b_m\Delta Q)$ are then summed and the *M.R.* obtained from equ. (10*a*), that

$$M=\frac{h^2}{(\epsilon_c+\epsilon_t)^2}\Sigma(b_m\Delta Q).$$

The work for each value of the extreme fibre strain may be set out as follows:

ϵ_x	x	Q	ΔQ	b	b_m	$b_m\Delta Q$
—	—	—		—		
			—		—	—
—	—	—		—		

In sections symmetrical with respect to the *C.L.* the mean values of b_m of the corresponding strips on each side of the centroid are equal, hence the calculation can be simplified by adding first the values of ΔQ using the expression

$$M=\frac{h^2}{(\epsilon_c+\epsilon_t)^2}\Sigma b_m(\Delta Q_c+\Delta Q_t), \text{ where } \Delta Q_c$$

and ΔQ_t represent the first moments of corresponding elements (equidistant from the stress axis, i.e. the *C.L.*) of the tensile and the com-

TABLE IV

CALCULATION OF THE MOMENT OF RESISTANCE OF THE BEAM AT $\varepsilon_e=0\cdot00768$

εx 10^{-1}	FIRST MOMENT (10^{-5} ton/in.) Qc	Qt	Qc+Qt	ΔQ	x in.	b in.	mean b_m in.	$b_m\Delta Q$ $10^{-5}\frac{\text{ton}}{\text{in.}}$
76·8	54692·89	57495·63	112178·51		0·8838			
				29422·83			0·1038	3053
67·8	40307·04	42448·64	82755·68		0·7800	0·2076		
				22489·47			0·2996	6750
59·8	29360·03	30906·13	60266·21		0·6880	0·3916		
				19103·14			0·4836	9235
51·8	20160·49	21002·57	41163·07		0·5960	0·5756		
				15581·85			0·6676	10410
43·8	12739·82	12841·40	25581·22		0·5040	0·7596		
				11415·94			0·8516	9720
35·8	7155·55	7009·72	14165·27		0·4120	0·9436		
				7709·73			1·0396	8015
27·5	3277·08	3178·47	6455·55		0·3160	1·1356		
				5184·08			1·2676	6580
16·0	645·08	626·08	1271·47		0·1840	1·3996		
				1271·47			1·5836	2015
0	0	0	0		0	1·7675		

$\Sigma b_m\Delta Q=$ 55778

$$M=\left(\frac{h}{2\varepsilon_e}\right)^2\Sigma b\Delta Q=\frac{1\cdot7675^2}{(2\times76\cdot8)^2}55778=7\cdot39 \text{ ton/in.}$$

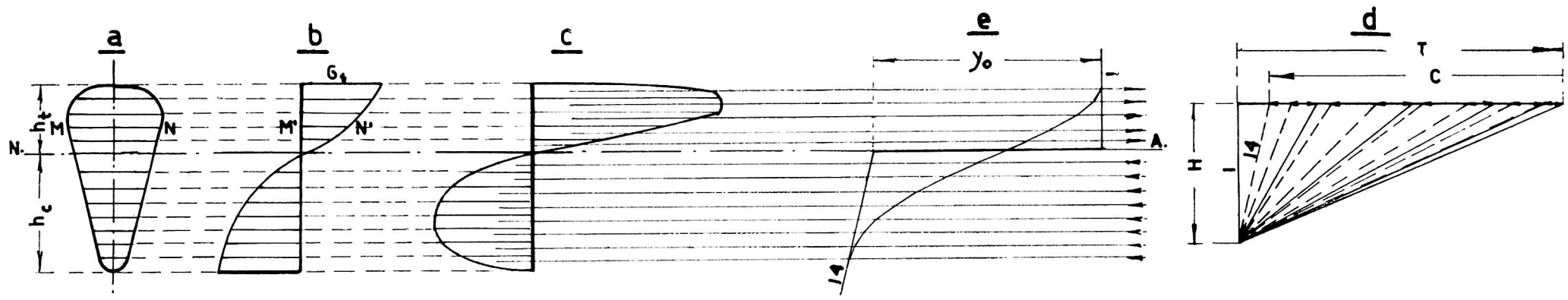


Fig. 4

pressive stress-strain curve. This case is illustrated in TABLE IV with respect to a square section of 1.25 inches side placed with a diagonal in the plane of bending; the values for Q were derived from TABLE III.

(*b*) Equ. (10*b*), i.e.

$$M=\int_{h_c}^{0}\sigma bxdx+\int_{0}^{h_t}\sigma bxdx$$

represents the sum of the first moments of the areas ($b\sigma dx$) with respect to the *C.L.* (*N.A.*). Accordingly the stress-strain curve is first plotted so that the stress axis coincides with the *C.L.* of the section given in FIG. 4*a* and to such a scale that the extreme fibre stress (say, in tension) is equal to the critical value σ_t. The stress distribution diagram, FIG. 4*b*, is thus obtained; it automatically determines the compressive stress σ_c at the distance h_c from the '*N.A.*' The cross-section and the distribution diagram are next divided into the corresponding elementary strips parallel to the *N.A.* The products (σb) such as (*MN*) (*M'N'*) from the corresponding diagrams are calculated and the diagram of ($b\sigma$), FIG. 4*c*, is plotted. The forces ($b\sigma$) Δx are next calculated where ($b\sigma$) denotes the mean width of each strip in FIG. 4*c* and Δx its depth. The points of application of the forces coincide with the centroids of the corresponding areas ($b\sigma\Delta x$). The moments of these forces about the '*N.A.*' (*C.L.*) are then obtained by multiplying the forces ($b\sigma\Delta x$) by their respective distances x_m from the *C.L.* The sum of the products ($x_m b\sigma\Delta x$) gives in accordance with equ. (10*b*) the *M.R.* of the cross section.

If a graphical solution is preferred the forces ($\sigma b\Delta x$) are drawn parallel to the *C.L.* at their corresponding points of application. The forces polygon FIG. 4*d* is next drawn and a pole chosen at an arbitrary vertical distance of H inches. The link polygon FIG. 4*e* determines the horizontal distance y_o measured in the scale of forces along the *C.L.* and the *M.R.* of the section is then

$$M=Hy_o.$$

It is evident from FIG. 4*d* that the origin and the end of the forces polygon do not coincide, i.e. the total compression and tension across the section do not create a real couple. This anomaly is a result of the assumption that the *N.A.* passes through the centroid of the section. The first and last links 1 and 14 are therefore not parallel to each other and the horizontal distance y_o is measured along the *C.L.*, because it was shown in Section III A2 that the error thus involved is negligible.

CONCLUSION

The general method for predicting the strength of beams theoretically can be applied to various materials and all types of sections even when the compressive and tensile portions of the beam are in various stages of deformation, e.g. the yield point was exceeded in one of the portions only. This affects the Q-ϵ functions but not the procedure in calculations as distinguished in refs. 29, 31, 42, etc.

A possibility of predicting the strength of beams for any limiting extreme fibre strains (or stress, etc.) may be also utilized in the 'theory of plasticity' ('Limit Design') without the necessity of determining the carrying capacity of beams experimentally. Similarly various values of, say, extreme fibre strains can be chosen and the corresponding *M.R.* found so that the relationship between the *B.M.* and the deformation (extreme fibre strains, curvature, deflections, etc.) can be plotted throughout any range required.

Ignoring *N.A.* shift it is only necessary to use the Q-ϵ function based on the stress-strain curve of the material (or the approximation to this curve) to determine the *M.R.* of any cross-section.

Trade Announcements

A monthly feature giving news of recent Government and professional appointments, industrial developments and business changes, etc.

New Airspeed Director

Mr W. F. Shaylor, business manager of Airspeed Ltd., Christchurch Aerodrome, Hants, for the past thirteen years, has been appointed to the board of the Company. He will continue to be responsible for all business and contractural matters in the Airspeed organization.

Armstrong Whitworth Publicity

Mr B. P. Hough has transferred to the Design and Technical Section of Sir W. G. Armstrong Whitworth Aircraft Ltd., Baginton, Coventry.

Mr W. T. Dickie is now handling Publicity and Technical sales matters.

B.A. Scottish Branch Office

Mr P. J. Ferguson has relinquished his appointment as Scottish Branch Manager of the British Aluminium Co. Ltd., Salisbury House, London Wall, E.C.2, which he has held since he joined the company in November, 1946, in order to take up a new appointment in the Head Office of the Company in London as Export Sales Manager. He assumed his new responsibility from January 1.

Mr M. J. J. Richards, of the Company's Midland Branch office, has been appointed Scottish Branch Manager in place of Mr Ferguson, and took over responsibility as from December 1.

Accident Investigations

The Minister of Civil Aviation, Lord Pakenham, has appointed Sir Walter Monckton, K.C., to hold a Public Court of Inquiry into the accident which occurred at London Airport on Tuesday, October 31, 1950, to the British European Airways Viking aircraft G-AHPN.

The names of the assessors will be announced in due course. Meanwhile the preliminary investigations by the Chief Inspector of Accidents are continuing. Further details, including time and place of the inquiry will be announced later.

The Public Inquiry into the causes and circumstances of the accident to the British European Airways Corporation Dakota aircraft at Mill Hill, London, N.W.7, will open at 10.30 a.m. on Monday, January 15, in the Hoare Memorial Hall at Church House, Westminster, London, S.W.1. The inquiry will be conducted by Mr J. Roland Adams, K.C. To assist Mr J. Roland Adams in the inquiry, Group-Captain J. A. Hawkings, O.B.E., and Captain C. B. Houlder, B.Sc., A.R.C.S., have been appointed as assessors.

Group-Captain Hawkings, O.B.E., is Command Engineer Office at R.A.F. Transport Command Headquarters.

Captain C. B. Houlder is a Senior Captain of the British Overseas Airways Corporation, and is at present flying Argonauts on the Far Eastern Service. He is a Bachelor of Science and an Associate of the Royal College of Science.

F. J. Edwards in Birmingham

F. J. Edwards Ltd., of 359-361 Euston Road, N.W.1, opened a new Sales Office in Birmingham on December 1 last. They have there a technical staff able to handle inquiries and give advice in the selection of sheet metal and plate working machinery and machine tools, tin box making and woodworking machinery and presses. Mr J. W. Langton, M.B.E., B.Sc.(Eng.), M.I.Mech.E., formerly Managing Director of Sheet Metal Technicians Ltd. and Sheet Metal Engineering Ltd., and previously with the Metal Box Company, Ltd., is in charge of this area.

The new Birmingham address is Lansdowne House, 41 Water Street, Birmingham, 3, and it will be headquarters for the area covering Midlands, N.E. and N.W. England, and Scotland.

Mr J. Hall, who has been on the technical staff at head office for some years, is moving to the same department in Birmingham.

A new member of the Birmingham Technical Staff is Mr A. Proctor, the outside representative covering the Northern Area. He will work from the Birmingham address, but can be reached at his private address at 19 Church Street, Pudsey, W. Yorks, for quick contact.

Gauge and Tool Exhibition

The third Gauge and Tool Exhibition to be organized by the Gauge & Tool Makers' Association, of 2 Old Bond Street, W.1, will be held in the New Hall of the Royal Horticultural Society, Elverton Street, Vincent Square, London, S.W.1, from Tuesday, May 15, to Friday, May 25, and will be open daily from, 10.30 a.m. to 7 p.m.

The following classes of engineering equipment, manufactured by members of the Association, will be displayed at the exhibition: Gauges and measuring equipment, jigs, fixtures and special tools, special-purpose machines and equipment, press tools, portable power tools, moulds and dies, engineers' small tools, and diamond tools.

New Graviner Director

Mr N. G. Bennett, M.B.E., A.R.Ae.S., has been appointed to the Board of Directors of Graviner Manufacturing Co. Ltd., Gosport Road, Gosport, Hants. He joined the Aircraft Equipment Division in 1946 in the capacity of chief engineer, and his knowledge and valuable experience of accident prevention and fire protection has greatly assisted the development of the company's products.

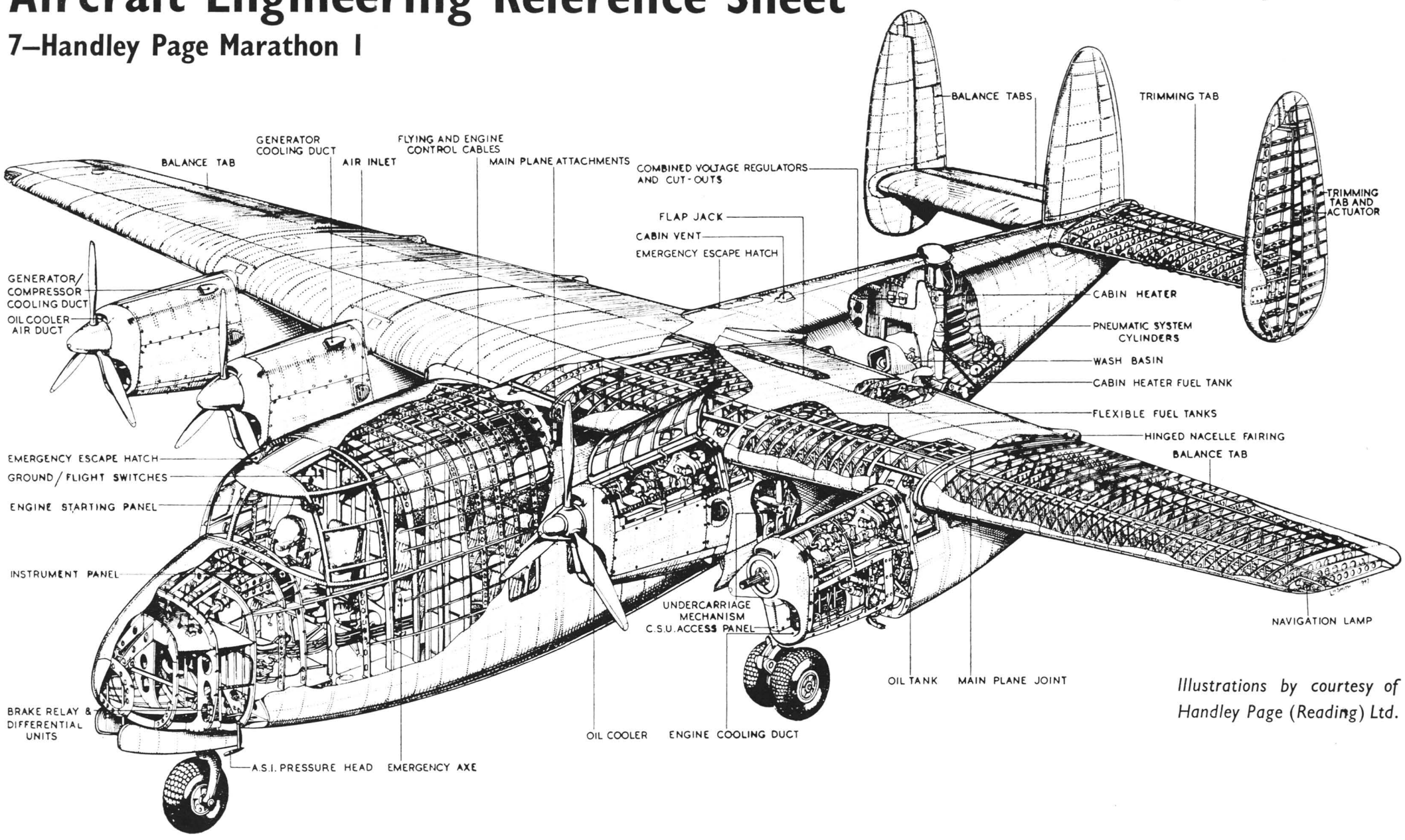
Woods of Colchester's London Office

Owing to their need for increased office space in London, Woods of Colchester Ltd., fan manufacturers (an associate company of the General Electric Co. Ltd.), moved their London offices on November 27 last to 58-62 High Holborn, W.C.1. Telephone number: Chancery 5474/8.

Aircraft Engineering Reference Sheet

7—Handley Page Marathon I

Prepared by T. Tonkin



Illustrations by courtesy of Handley Page (Reading) Ltd.

The Marathon I (M.60) is an all-metal, short/medium-range aeroplane capable of carrying a maximum of 22 passengers or, by simple adaptation, freight and mixed cargo. Two flight crew (first pilot and second pilot/navigator) are carried; radio is installed immediately aft of the cockpit on the starboard side while directly opposite this location provision is made for a forward freight compartment or a seat for a third crew member. A toilet can be fitted on the left-hand side of the passenger cabin just aft of the entrance door and a space at the rear on the-right hand side can be utilized as a wardrobe.

The overall skin completely seals the fuselage from the main plane isolating fuel and oil vapours and improving sound and heat insulation. Cabin sound proofing and heat insulation is by Fibreglass panels clipped to the structure so that airspaces are left between the outer layer and the skin and between the inner and outer layers; the panels extend to floor level.

Passenger seats are of double arm-chair type with welded light alloy tube frames and rubber cord seat and back-rest cushion bracings. The seats are easily removed by withdrawing the four bolts which secure them to the floor anchorages.

PERFORMANCE

Data based on 18,000 lb. all-up weight:

Distance to clear 50 ft. from runway in still air (yd.):	*Sea level*	2,500 *ft.*	5,000 *ft.*
Four engines	1,030	1,130	1,215
Three engines	1,150	1,260	1,370
Take-off safety speed	90·5 knots E.A.S.		81 knots I.A.S.

Climbs and Heights

	Sea level	5,000 *ft.*		10,000 *ft.*	
	ft./min.	*ft./min.*	*time*	*ft./min.*	*time*
Four engines, climb rating	684	710	7	630	14
Three engines, climb rating	240	235	21	140	43·5
Recommended climbing speed				100 knots I.A.S.	
Service ceiling (ft.)					18,500
Absolute ceiling (ft.)					20,100

Speeds

Cruising (knots T.A.S.)	*Sea level*	5,000 *ft.*	10,000 *ft.*
Max. cruising power	167·3	179·0	182·2
Max. weak mixture power	161·4	172·8	181·8
Max. level (knots T.A.S.)			
Take-off power	182·6	195·7	196·2
Max. cruising power	167·3	179·0	182·2
Max. weak mixture power	161·4	172·8	181·8

Ranges (air miles) with per cent allowance for run-up, take-off, climb and landing:	*Sea level*	5,000 *ft.*	10,000 *ft.*
Max. weak mixture power	778 (5·4)	785 (5·8)	845 (2·9)
Max. economical weak power	1,000 (5·0)	1,025 (7·3)	1,030 (2·2)

Stalling speeds

	Power off		*Level flight power*	
	Knots I.A.S.	*Knots C.A.S.*	*Knots I.A.S.*	*Knots C.A.S.*
Wheels, flaps up	77	89·5	66	81
Wheels up, flaps at take-off	64·8	78·4	58	75·5
Wheels up, flaps down	62	76	52	61
Wheels down, flaps at take-off	65·3	78·7	55	64
Wheels down, flaps down	62·1	74·6	55	74
Landing speed, flaps down	89·5 knots E.A.S.		82 knots I.A.S.	

Touchdown speed, flaps down	80·5 knots E.A.S.	70 knots I.A.S.

Distance to rest from 50 ft., still air, without reverse pitch (yd.):

	Sea level	2,500 *ft.*	5,000 *ft.*
Four engines	790	840	895
Three engines	988	1,035	1,090

Limitations

Max. permissible	230 knots
Max. wheels down	140 knots
Max. for flaps—full down	115 knots
take-off	130 knots

LOADINGS

(Considerable variations exist between individual aircraft owing to seating, equipment, radio, etc.)

	lb.
Empty weight	10,884
Tare weight with radio, less fuel, oil, crew, passengers and cargo	11,576
All-up weight—max.	18,000
Wing loading at max. all-up weight	36·14 lb./sq. ft.
Power loading (take-off/max. all-up weight)	13·31 lb./b.h.p.
Max. floor loadings	*lb./sq. ft.*
Cabin	75
Freight compartments	100
Max. load	*lb.*
Front freight compartment	750
Rear freight compartment	1,200
C.G. datum point location	Plate on fuselage side below leading edge of main plane at 49·50 in., from centre line of fuselage
C.G. limits—forward	24·74 in. aft of datum
aft	37·06 in. aft of datum

DIMENSIONS

Fuselage

Length overall	52 ft. 3 in.
Width, max.	8 ft. 0 in.
Height, max.	8 ft. 0 in.
Cabin length	18 ft. 0 in.
Min. height	6 ft. 0 in.
Max. width	7 ft. 9 in.
Volume	989 cu. ft.

Main Plane

Span	65 ft. 0 in.
Chord—root	10 ft. 1 in.
tip	4 ft. 8½ in.
Height of wing tips	10 ft. 3½ in.
Incidence—root	4 deg. 30 min.
tip	2 deg. 30 min.
Dihedral	Nil
Aspect ratio	9·9
Aerofoil section	N.A.C.A. 230 series

Tail Plane

Span	20 ft. 0 in.
Chord—root	5 ft. 9 in.
tip	4 ft. 3 in.
Incidence—at root and at tip	—1 deg. 30 min.
Dihedral	—28 min.
Aerofoil	N.A.C.A. 0012 modified

AREAS

	Sq. ft.
Fuselage, total wetted minus wing and tail plane roots	976·00
Main plane—gross	498·00
net	426·00
Ailerons—each	30·20
balance tabs, each	1·8
Flaps, total	65·80
Tail plane—total	99·00
net	88·00
Elevators—gross	78·26
trimming and balance tabs, each	1·97
Fin, total	76·00
Rudder—total	54·00
trimming and balance tabs, each	1·34

CONTROL SURFACE MOVEMENTS

Ailerons—	*Angular*	*Linear (in.)*
at inboard ends	up 24°	8·43±0·25
	down 14°	4·94 −0 +0·25
balance tabs (both)	up 24°	2·37±0·05
	down 14°	1·39±0·05
Flaps—		
take-off	19° 8′±1° (inb'd)	
	22° 23′±1° (outb'd)	
down	39° 8′±1° (inb'd)	
	42° 23′±1° (outb'd)	
Elevators	up 30°	12·88±0·25 (inb'd)
		9·30±0·25 (outb'd)
	down 15°	6·50±0·25 (inb'd)
		4·68±0·25 (outb'd)
Balance tab (starb'd)	up	0·63±0·05
	down	1·26±0·05
Trimming tab (port)	up	1·57±0·05
	down	1·57±0·05
Rudders, at max. chord position	outboard 30°	12·42±0·25
	inboard 25°	10·39±0·25
Balance tab (starb'd)	outboard	1·73±0·05
	inboard	2·07±0·05
Trimming tab (port)	outboard, inboard	1·70 — 1·18±0·05 each way; for 17° trim 1·60

Control Cable Sizes and Tensions

All tension figures are given to a mean temperature of 60°F.

Circuit	*Size (cwt.)*	*Tension (lb.)*
Ailerons	15	100±5
Flaps	20	100±5
Elevators	15	65±5
	10	Removal of slack only
Rudders	15	100±5

ALIGHTING GEAR

	Main wheels	*Nose-wheel*
Shock absorbers	Oleo-pneumatic H.P. Drg. No. 6066078	Oleo-pneumatic H.P. Drg. No. 6067002
Fluid	D.TD.585 (3·47 pints)	D.TD.585 5⅛ pints)
Air pressure, no load	450 lb./sq. in.	110 lb./sq. in.
Wheels, Palmer	868 B. Mk. 2	868
Covers, Palmer	PBE 69	PBE 67
Tubes, Palmer	PB 70	PB 70
Air pressure, average, on ground	59 lb./sq. in.	59 lb./sq. in.
Track	17 ft. 4 in.	
Brakes	Palmer pneumatic	
Wheel units	Palmer 868/50P Mk. 2	
Differential unit	Palmer 706B	
Operating pressure	180 lb./sq. in.	

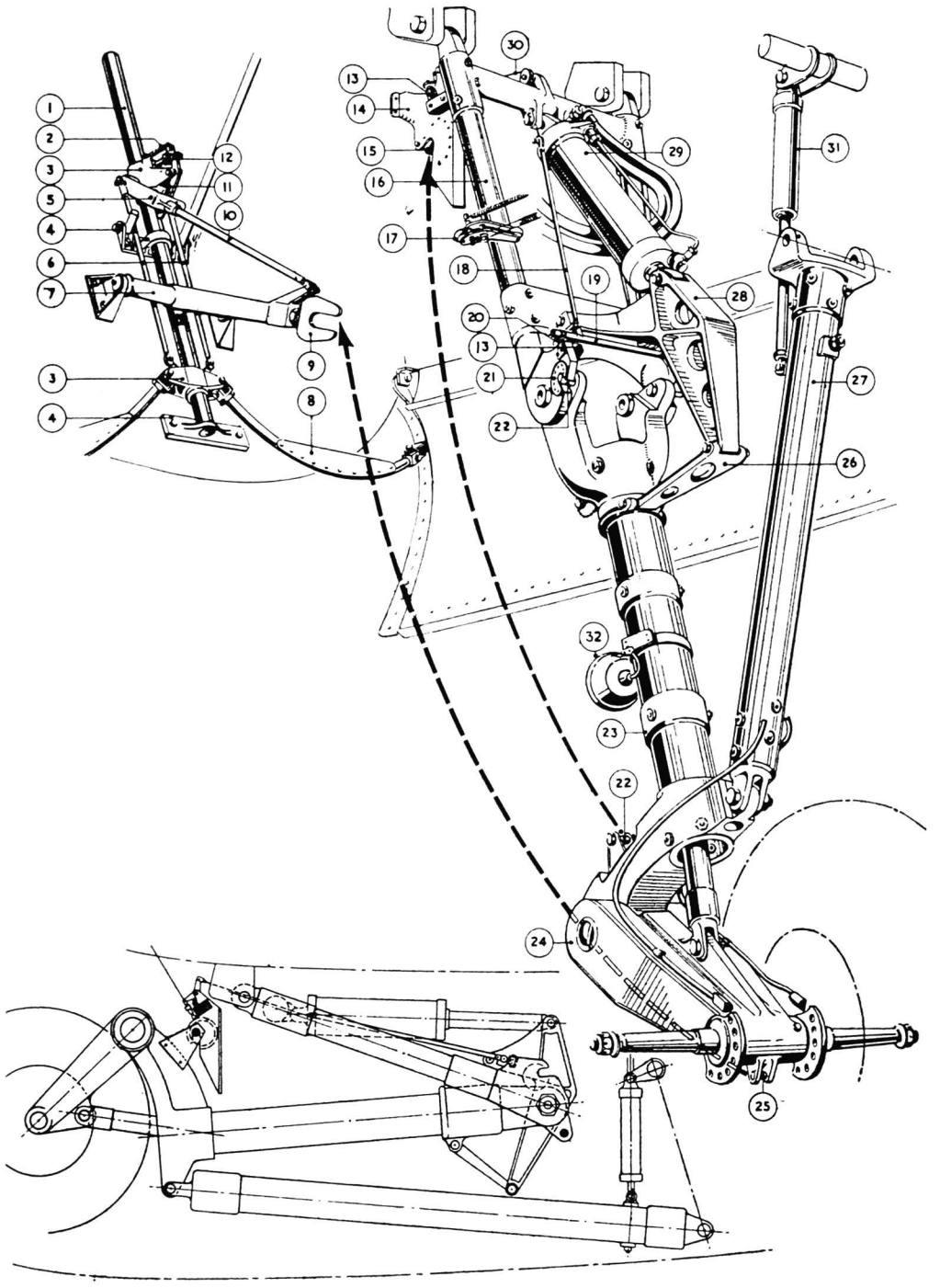


Fig. 1.—Main undercarriage unit

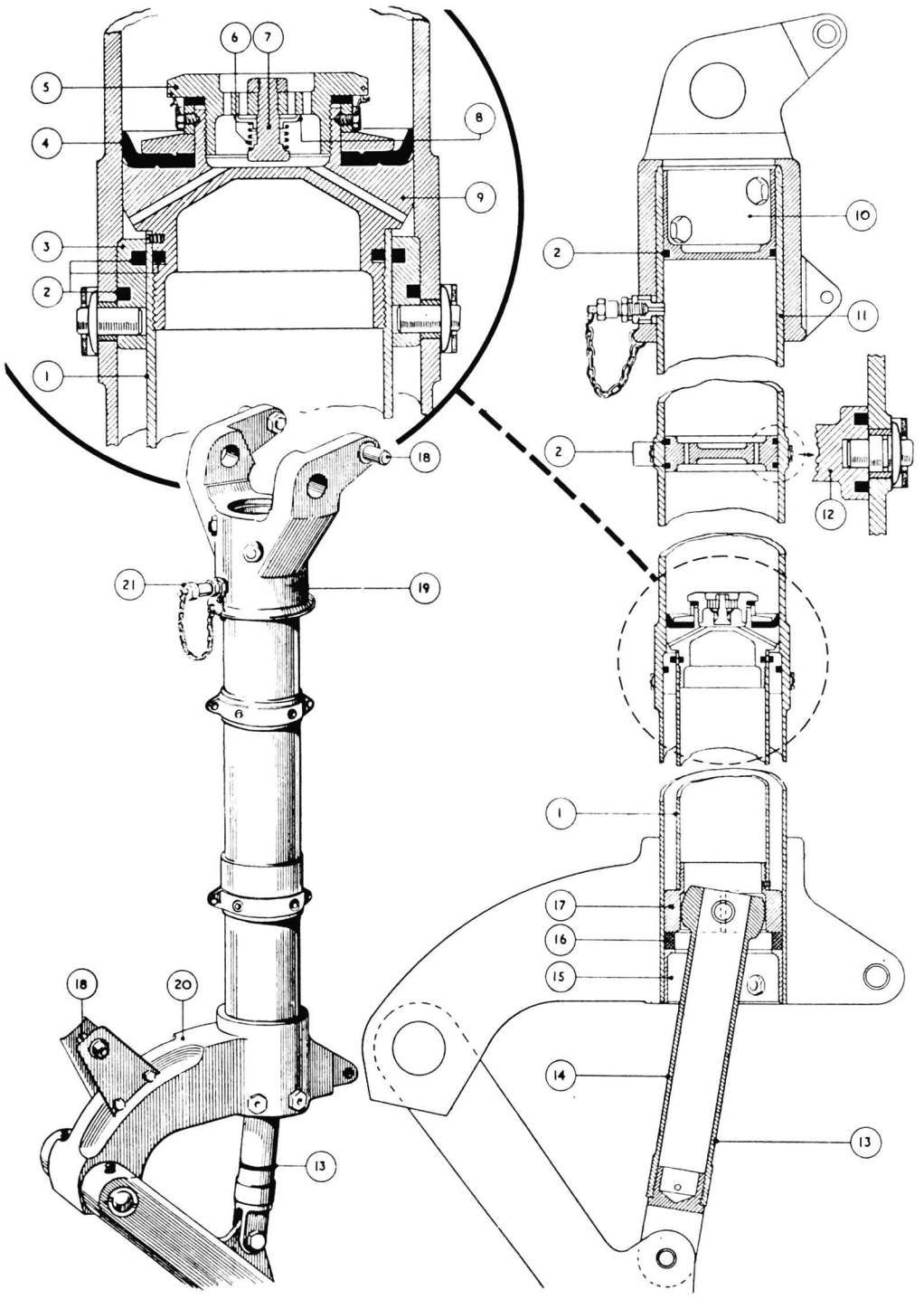


Fig. 2.—Main undercarriage leg

PNEUMATIC SYSTEM

See **Fig. 7** and its key for location of components and part numbers, to be published next month.

VACUUM SYSTEM

Pumps	Plessey B3X or Turner Romec B3 Mk. 2
Suction relief valves	Plessey 215B

AIR CONDITIONING SYSTEM

Cabin heaters	Daniel X-lg-D
Fuel	87-100 octane D.E.D. 2473
Tank capacity	2·5 Imp. gals.

De-icing Systems

Aerofoil	Thermal or Goodrich, details not available
Windscreen Pump	Dunlop AH 8029
Fluid	D.T.D. 406A
Capacity	1 Imp. gal.

FIRE EXTINGUISHING SYSTEMS

Containers, engine	Graviner Mk. 4 (6 lb.) methyl bromide
cabin heater	Graviner Mk. 6 (1 lb.) methyl bromide (27N/53)
Inertia switches	Graviner 900 (27N/20) and 805E (5C/3521)
Flame switches	Graviner 220E Mk. 3 (27N/72)

ELECTRICAL

Generators	2 Newton HX2-24V, 1000W or 3 Rotax B2001-24V, 750W
Accumulators	2 Exide 6 FZ11-3-12V, 40 A.hr.
Combined cut-outs and regulators	Newton type A2
Power supply suppressors	Type Y No. 3 (A.M. Ref. 5C/3085)
Voltmeter (0-40V)	Type C (A.M. Ref. 5Q/1693)
Ammeter (0-60 amp.)	Turner IS.1242
Master switches	Type C (A.M. Ref. 5C/2828)
External supply socket	B.TH. Type E.2 (A.M. Ref. 5C/2225)
Starter and feathering motors	Rotax C.4602
Landing lamp	Type J (A.M. Ref. 5C/1515)
Wiring system	Single pole, earth return

RADIO

Details not available

INSTRUMENTS

Airframe

A.S.I.	Smith 115AS/PC
Air thermometer bulb	Smith 59MV
Altimeters	Weston S.110 Form 5
Artificial horizon	A.M. Type Mk. 14A Ref. 6A/1273
Auto-pilot pressure gauge	A.M. Type Mk. 1B Ref. 6A/1519
Cabin thermometer bulb	Sperry Mk. 8M
Clock	Smith 46MV
Compass	A.M. Type Mk. 2 Ref. 6A/1407
Directional gyro	Smith 5ACA
Elevator and rudder: trim tab indicator	Smith 295FL
transmitter	A.M. type 6A/2131
Flap indicator	Smith 218FL
transmitter	A.M. type 6A/2131
Rate-of-climb indicator	Smith 20RC/PC
Turn-and-bank indicator	Hughes V263
Undercarriage position indicator	Smith 35CFP
Vacuum gauge	Smith 257/PG/PC
Wheel-brake pressure gauges	Smith 303PG
Pilot aid	Sperry AL 1
Pitot head	A.M. type Mk. 8D Ref. 6A/731
Current flow indicator	Rotax F.1601

Engines

Boost gauges	Smith 74BG
Gill indicators	Smith 221FL
transmitters	A.M. type C. Ref. 6A/2133
Cylinder head gauges	Smith 87MV
thermocouples	Weston Mk. 4A
Engine speed indicators	Smith V.138
transmitters	A.M. type Mk. 4 Ref. 6A/780
flexible drive	A.M. type (1 ft. 6 in.) Mk. 7 Ref. 6A/1485
Fuel contents gauges	Smith Inboard 1256FG Outboard 1258FG
transmitters	Smith Inboard 1255FG Outboard 1257FG
Fuel pressure gauges	Smith 82MV
transmitters	Smith 290PG
Oil pressure gauges	Smith 83MV
transmitters	Smith 267PG
Oil temperature gauges	Smith 85MV
thermometer bulbs	A.M. type Mk. 3 Ref. 6A/1566
Synchroscope (special order)	K.B.B. Type 301-02

POWER UNITS

Type	De Havilland, Gipsy Queen 70-2 (Marathon)
Fuel	100 octane, DED 2475, 100/130 grade
Oil	Arctic DED 2472A/O Temperate DED 2472/B/O Tropical DED 2472C/O
Oil pressure, normal, 2,400 r.p.m., inlet temp. 68-72°C.	55 to 60 lb./sq. in.
Emergency min.	40 lb./sq. in.

PROPELLERS

Type	De Havilland, hydromatic, constant speed, feathering and braking, 3/1000/2, PD25/312/1, PD83/312/1 or 2
Diameter	7 ft. 6 in.
Pitch ranges	−26° to 94° (PD25) −20° to 100° (PD83)
Settings	Fine pitch 19° Feathered 87°
Constant speed units	D.H. PAY30000/B, PAY30002 (PD25), PAY30004 (PD83)
Feathering pump	D.H. PFD2000 (PD25) PFD2200 (PD83)

FUEL SYSTEM

Tanks	Hycatrol flexible crashproof
Capacities—	*Normal* (4) *Auxiliary* (4)
per tank	55 Imp. gals. 15 Imp. gals.
total	220 Imp. gals. 60 Imp. gals.
Fuel pressure	Min. 20 lb./sq. in. Normal 27 ± 2 lb./sq. in.
Fuel injectors	Hobson DH/GL. continuous injection type
Immersed pumps	Self Priming BP14 Mk. 1
Priming pump, pneumatic	Handley Page Pt. No. 6008054
Filters, main supply	Amal 266/1
priming supply	Lockheed A.I.R. 40836

OIL SYSTEM

Tanks	Welded aluminium
Capacities (per engine)—	*Imp. gals.*
total	7¾
air space	1¾
feathering reserve	1
effective capacity	5
Cooler	Delaney Galley E.3260

IGNITION

Magnetos*	B.T.H. CGA/1, CGA/4 Mod. 1390, CGD Mod. 1422 (Screened): Rotax NGA
Distributors	BTH CDGA/1 (Screened): Rotax NDGA/1
Impulse starter	BTH Z1-11
Sparking plugs	K.L.G. KH1 (K42 1R), RC9-2R: Lodge L.H.1, RS9-1R

* Early engines have ignition control with CGA or NGA magnetos; later engines with fixed ignition have CGD magnetos.

Characteristics and Limitations

	Height (ft.)	*b.h.p.*	*r.p.m.*	*Boost (lb./sq. in)*	*Temperature °C. Cylinder*	*Oil*	*Consumptions Fuel Gals./hour*	*Oil Pints/hour*
Take-off, max.	Sea level	325/340	2,800	+6	280	100	32·75	10
Climb, max. (international) / Cruising, max.	8,000	285/295	2,600	+3	260	90	26·5	8
Cruising, max. emergency (60 min. limit)	5,000	330	2,600	+5	260	90	31·0	8
Cruising, max. weak mixture	8,000	265	2,400	+2	250	80	17·5	6
Emergency max. (15 min. limit)	5,000	355	2,800	+6	280	100	34·25	10

STRUCTURE

Fuselage

A light alloy stressed skin structure with lapped panels mainly 20-24 s.w.g. but with 18 s.w.g. skin near the tail. Closely spaced frames are of 20 or 22 s.w.g. channel sections with doubled box frames of 18 s.w.g. for the centre section spar loads and for the tail plane. The channel section longerons are continuous except at the spar frames where the loads are carried through the frames by tubes. The longerons are attached to the inner flanges of the other frames by anchor plates. The lipped L-section stringers pass through clearance notches in the frames. The main floor is supported on deep longitudinal and lateral members that are shaped to allow space for the air-conditioning equipment. Except in the gangway area, which has Onazote panels, the floor is of reinforced plywood. A light alloy floor is used for the cockpit.

Centre Section

The main spar (at 30 per cent chord) has a light alloy web with extruded L-section booms and vertical Z-section shear members. Most ribs have L-section booms with channel braces, the fuselage attachment ribs are Warren girders. The centre section skin varies between 26-16 s.w.g. Centre section-outer plane joints are fore-and-aft bolts through the spar booms.

Outer Planes

The structure is similar to that of the centre section save for the detachable leading edges fitted to all but the first four aeroplanes. Two types of leading edges are available, one with Goodrich de-icing shoes and the other with a thermal system—these are interchangeable. Attachment is by bolts and anchor nuts.

Ailerons

The spar is a light alloy web with L-section booms, pierced diaphragm ribs and a light alloy skin. The lead mass balance weight projects through the leading-edge skin into the wing. The tabs, which have a channel spar and light alloy skin, are attached to the top surfaces of the skin by a piano hinge.

Flaps

The extension flaps are of Miles design and their aerofoil section is built-up with a single channel section spar, light alloy ribs and skin.

Nacelles

The stressed skin nacelles are attached to the wing permanently, although not considered as part of the main structure. The inner nacelles are stronger than the outer, since they carry the wheel loads, but the outer ones contain the flap mechanism in their rear fairings.

Tail Unit

The tail plane spar has a plain web with L-section booms. The root ribs are Warren girders, the remainder being pierced flanged blanks. The skin panels are mainly 20 or 22 s.w.g.

The elevator has a solid web spar with L-section booms, light alloy ribs and covering. The light alloy torque shaft joining the spars to the two halves, carries the operating lever to which is attached the mass balance weight in the fuselage. The trimming tab in the port elevator is electrically operated. The gearing of the balance (starboard) tab is adjustable.

The three fins are generally similar in construction and resemble the tail plane, save that they have two spars. Like the latter the leading edge is designed to take either Goodrich de-icing shoes or thermal de-icing equipment.

The rudders are similar to the elevators in construction with light alloy skins. The mass balances are mounted in the horns. The port rudder has an electrical trimming tab, the starboard a balance tab.

On the tail unit the leading edge skin is flush riveted, with mushroom headed rivets aft, save where Tucker hollow rivets are used.

UNDERCARRIAGE

Main Wheel Units (Figs. 1 and 2)

During retraction the pneumatic jack 29 extends, initial movement causing the cylinder to ride up on its top attachment pin, so pulling the tie rods 18 and releasing the spring-loaded lock plungers from the downlocks 21 while, simultaneously, the cable 30 pulls a spring-loaded pawl from its recess in the uplock jaws 14 leaving them free to receive the locking pins 22. Further extension of the jack pivots the frame 16 rearward, after releasing the locking pins 22 from the cams 21, and swings the shock absorber 23 and drag strut 27 forward. The damper piston, between the drag strut 27 and the nacelle, retracts into its cylinder 31. When locked up, the jack is fully extended and the pins 22 enter the jaws of the uplock 15, rotate the body and allows the pawls to drop home.

When lowering, the initial jack movement operates the cable 30 and disengages the uplock pawl. During the final stages of lowering spring-loaded assisters 17 snap the units into the locked position.

The hydraulic damping cylinder is tapered internally at its lower end and carries a piston with a series of restrictor holes and a floating gland. During retraction the piston moves freely for the first third of its travel, due to the taper clearance, until the gland ring is forced on to the bottom of its groove, when fluid can only pass through the restrictor holes, so damping the retraction. A reversal of the process damps initial lowering of the main wheels.

The oleo-pneumatic shock-absorbers contain air in the upper part of the cylinder 11 to balance the static load. In action, as the piston rises in the cylinder it compresses the air and forces fluid down through the holes in the compression stop 2 and, at the same time, the spring-loaded flutter plate 8 unseats and fluid passes through all the holes in the flutter valve body 5 and thence by the drillings in piston head 9 into the annular space around it and the gland ring 3. On the rebound the action is reversed, damping being achieved because the flutter plate reseats and blanks the inner ring of holes throughout the stroke.

Nose Wheel Unit (Figs. 3 and 4)

The action of the retracting mechanism is clearly shown in **Fig. 3.** When retracting, the initial jack movement rotates levers 10 and 11 until a pad abuts a stop on the pivot casting, simultaneously withdrawing the down-lock plunger, allowing the uplock plunger to bear on the profile of the cam 6. When retracted, cam 6 engages the pin 3 which rotates it until the plunger 7 engages and locks the unit.

The steering mechanism allows a 5 deg. combined angle of movement of the nose-wheel. It comprises a steering lever 14, attached to the nose-wheel leg and operated, through the linkages shown in **Fig. 3,** from the rudder bar. A spring-loaded locking pin is controllable from the cockpit by Bowden cable. When this pin is engaged and with the wheel down, rudder bar movement actuates arms 13 and 16, rod 15 and lever 14 to pivot the wheel. When the wheel is retracted, arm 16 moves up under the hinge of 13 so that it is no longer affected by rudder bar movements.

The shock-absorber piston 18, **Fig. 4,** is supported by air pressure under static load. In action fluid passes down through the hole in the piston head and also through the outer drillings and fluted needle valves into the space between the piston and cylinder walls. When the load is relieved air pressure forces the separator 16 upward, so forcing fluid back into the space above the head. The drillings at the ends of the valves are now sealed, thereby reducing the rate of fluid return and damping the recoil.

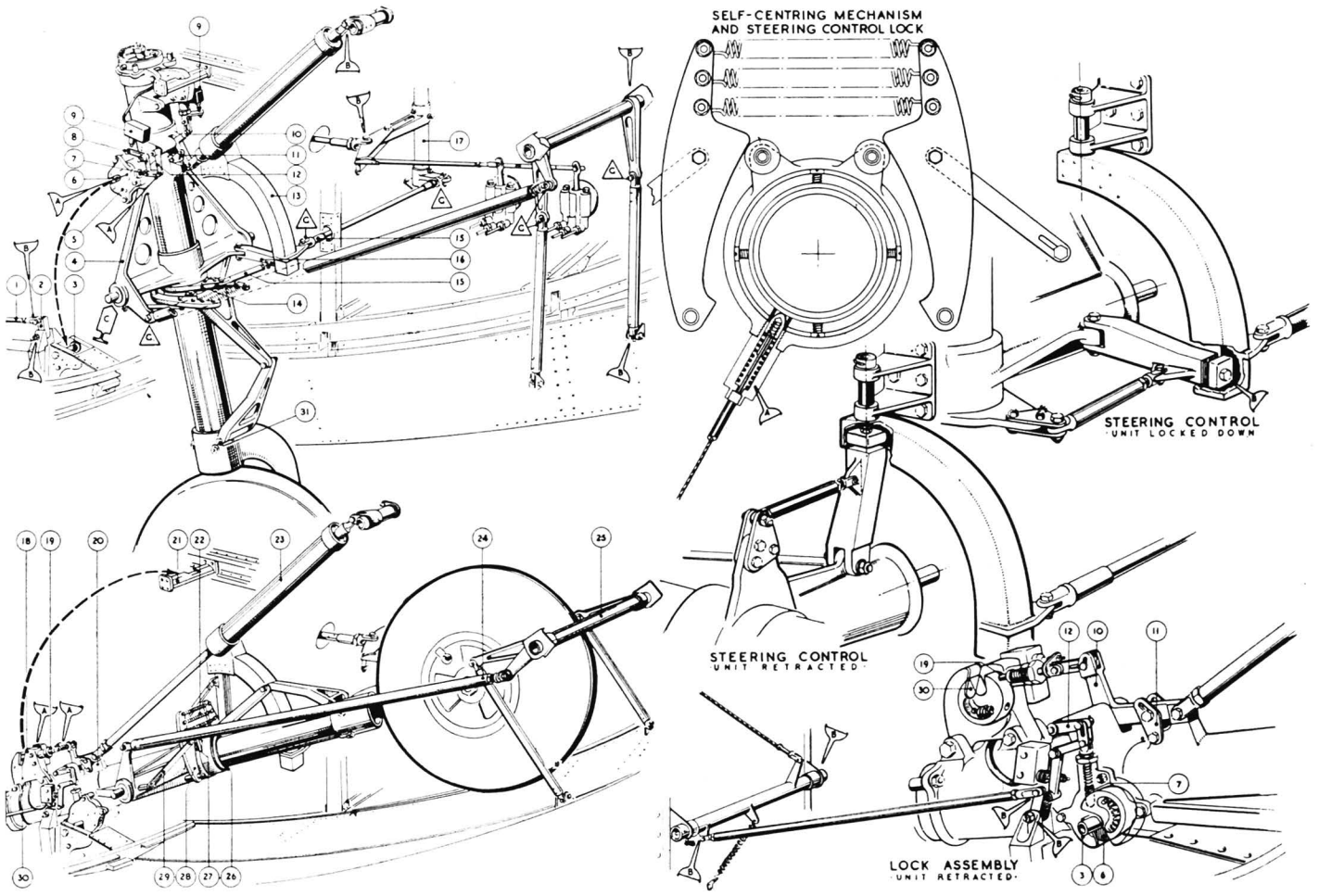


Fig. 3.—Nose wheel unit

Emergency Lowering

Main and nose-wheels can be lowered by selecting DOWN and operating a handle to the left of the control pedestal. The handle, which has a spring-loaded knob, operates a shaft and cable system that releases the uplocks, after which the units fall and lock by gravity.

FLYING CONTROLS

The handwheel assemblies consist of a torque tube for the ailerons, mounted in two ball-bearings, inside which, running on rollers, is the square-section tube that is connected at its forward end to the elevator control linkage. The rudder pedals and parallel-motion assembly are carried on a torque shaft that passes through a bracket on the floor. A knob on the dash, connected by Bowden cable to a plunger engaging in holes in the supporting tube, is used to adjust the pedals.

Where dual control is not fitted the starboard torque shaft is still mounted because its rear sprocket is part of the aileron system.

Fig. 5 shows diagrammatically the parts already described, as well as giving the general features of the remainder of the cable runs. Elevator cables are duplicated throughout with one set of 15 cwt. and another of 10 cwt. cables. There are balance tabs on all controls and electrically-operated trimming tabs on rudder and elevator. The flaps are operated by a double-acting pneumatic jack (port) through a system of chains and cables. The jack actuates a geared quadrant that meshes with a gear between two cable drums—the rear drum for the port and the forward drum for the starboard flap. Each cable is attached to a chain that passes round the rearmost of three sprockets midway between each pair of

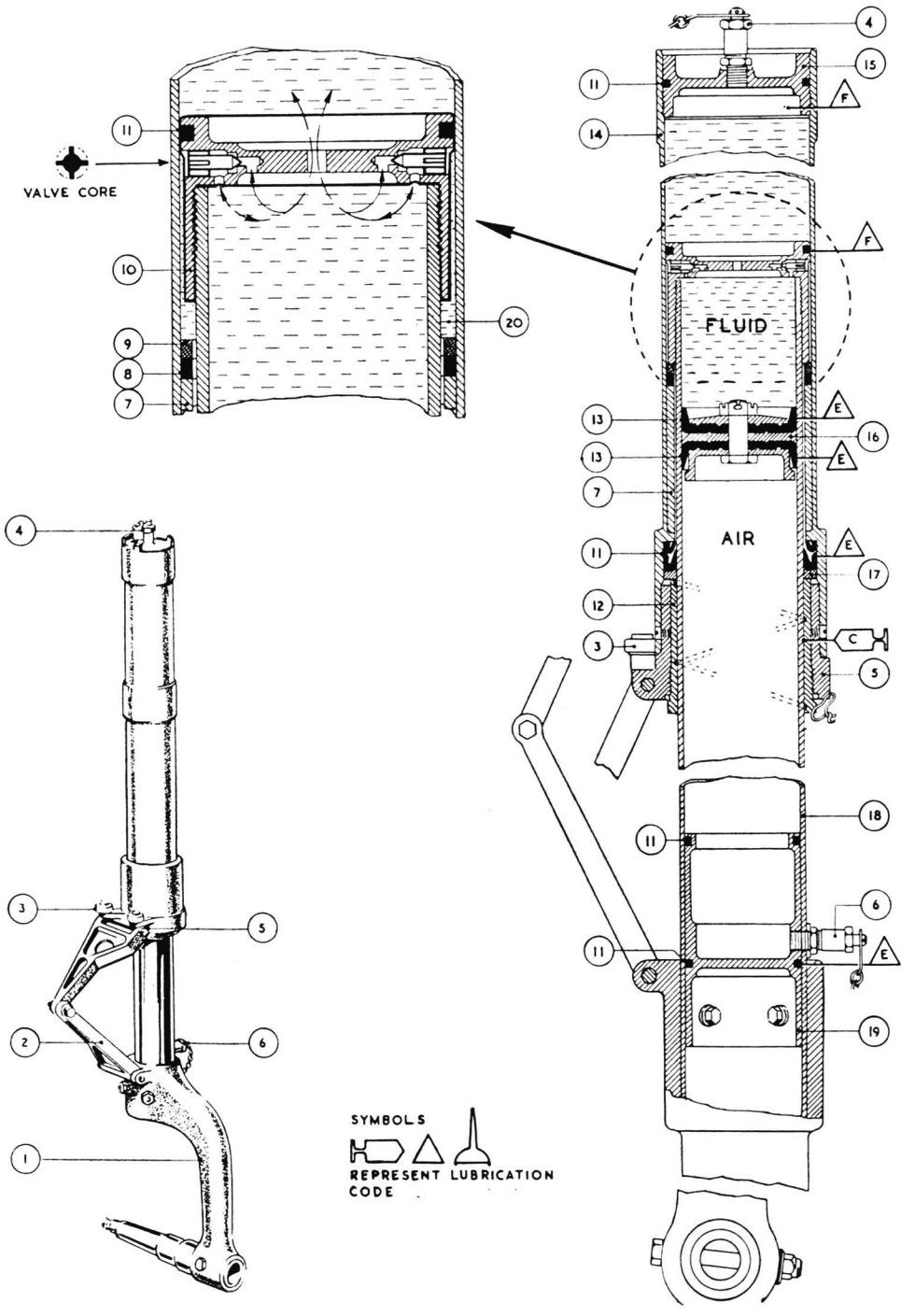


Fig. 4.—Nose wheel leg

The symbols in this drawing, and those in Figs. 1, 2, and 3, are a lubrication code showing where oiling and greasing are required

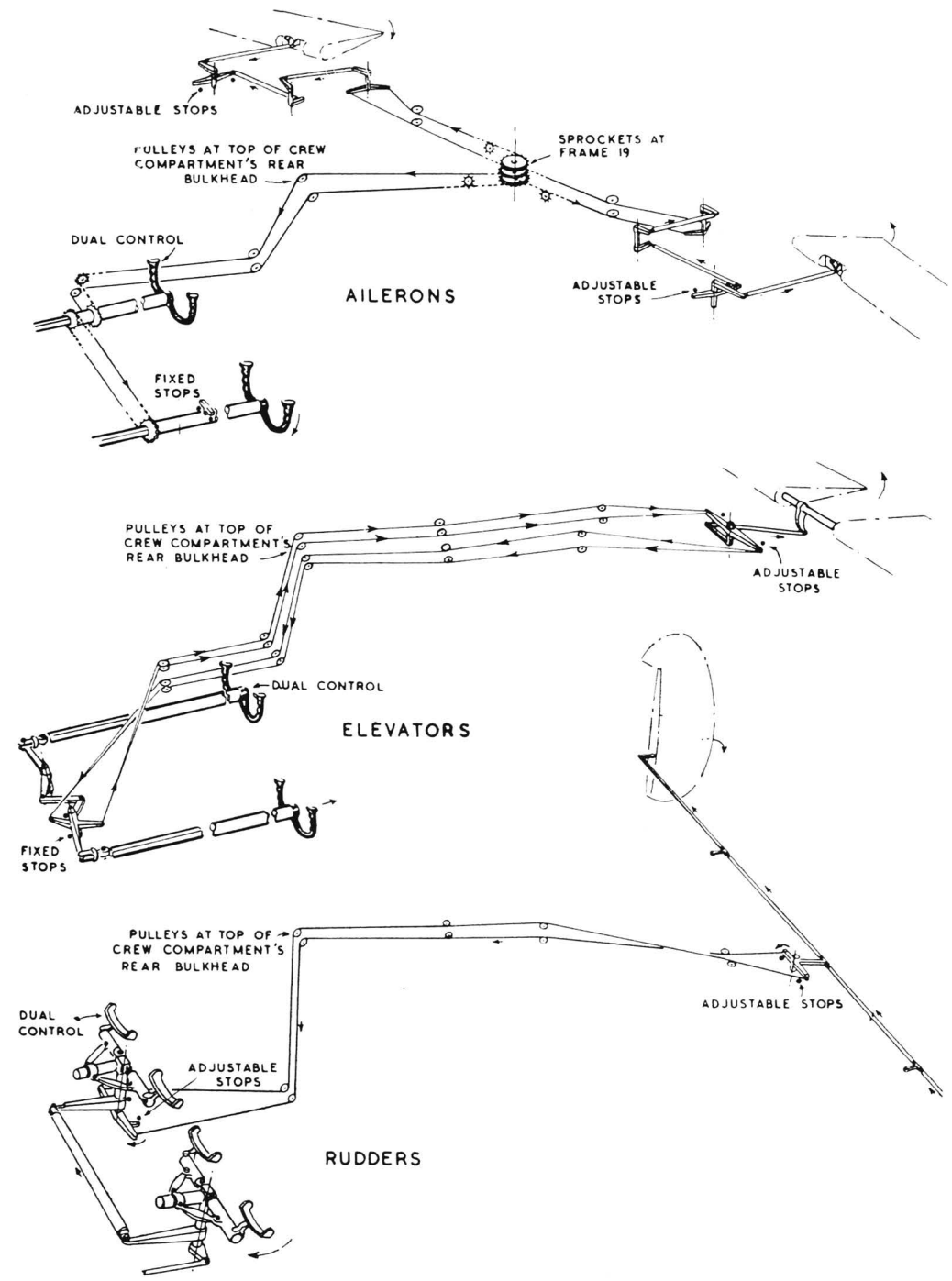


Fig. 5.—Diagrammatic layout of flying control runs

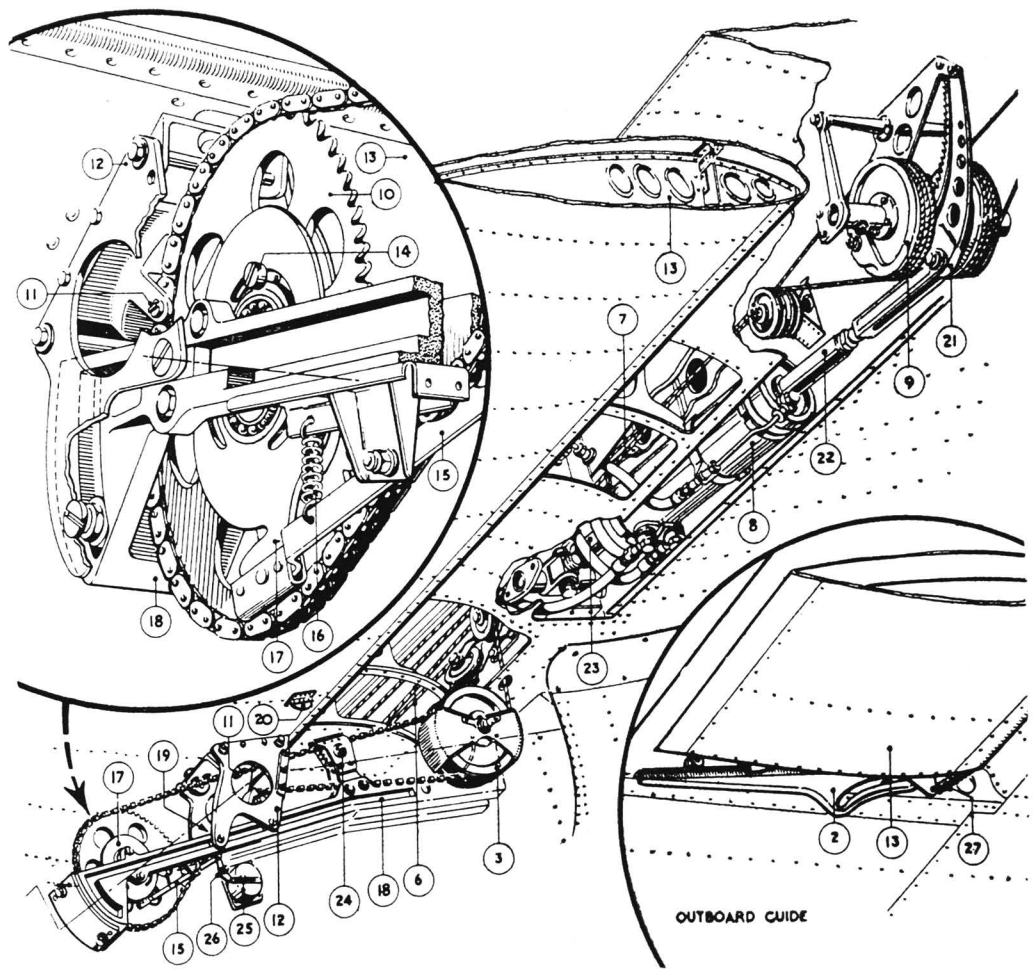


Fig. 6.—Flap actuating mechanism, port shown

nacelles. Chain-and-cable circuits lead from the centre sprocket to the inner, and from the forward sprocket to the outer nacelle operating drums. The action of the guide rails and carrier chains can be seen from **Fig. 6.** The pilot's selector has three positions: fully forward the jack is closed and the flaps are retracted; in the mid position the jack is partially extended and the flaps are in the take-off position: while with it aft the jack is fully out and the flaps right down. Each flap has extending supporting guide rails at either end which slide in guide brackets on the main plane, following the flap movement.

AUTO PILOT

A Sperry AL 1 Pilot Aid can be fitted; the main components of which are a gyro relay (containing a gyro, two torque motors and two pneumatic valves); a directional gyro, electrically connected to the gyro relay; a pilot's control unit, also electrically connected to the gyro relay; an elevator servo; and a combined pressure regulator/oil separator with a relief valve set at 10-12 lb./sq. in. Pressure for the system comes from the vacuum pump exhaust of the port outer engine. The elevator ram is attached to a lever on the linkage forward of the control columns, extension moving the elevators down. The aileron servo is attached to a lever on a drive unit consisting of a 60-tooth sprocket with a lever attached, which drives a 25-tooth sprocket, on the right-hand control column torque shaft, by a $\frac{3}{8}$ in. pitch chain. These units are in a chain case which embodies a chain-tensioning adjuster.

VACUUM SYSTEM

Two pumps (outer engines) supply through regulators on the rear of the firewalls and non-return valves at the top of frame 5—there is no changeover cock. The lines unite behind the instrument panel to supply the artificial horizon, direction indicator and suction gauge. A duplicate set of instruments can be connected through an on/off cock. Pipes are mainly aluminium alloy, with flexible hoses at the instruments, and steel pipes forward of the firewalls.

AIR CONDITIONING

The two cold air ducts (part of the fuselage floor structure) extend the length of the cabin and are fed from a controllable scoop at the forward end of each. Pipes from the ducts are connected to louvers at the passenger seats. Air extracted through two controllable box ducts in the roof is exhausted by extractors on the top of the fuselage.

The hot air ducts (beneath the floor on top of the cold air ducts) have outlet grills in the cabin fed from branch pipes connected to the combustion heater in the rear fuselage. A third branch pipe from the heater passes forward beneath the floor to frame 5 where it divides to feed windscreen de-misting distributors. The hot air shutter at the bottom of the heater is controlled by an electric actuator. This system can also be used to supplement the cold air supply when the heater is not working. The heater air intake and exhaust pipes are combined in a forward-facing fairing at the top rear of the fuselage, the exhaust gases after heating the air intake pipe escaping through perforations at the rear of the fairing. A shroud vented to atmosphere is fitted around the heater. A thermostat cuts out the igniter plug at a predetermined temperature and a second thermostat shuts off the heater in the event of fire or excessive temperatures. An electrical fuel pump on a box structure beside the heater is cooled by air circulating through short ducts which project through the fuselage skin. The fuel tank is opposite the heater on the port side, the filler neck being reached through an inspection door.

DE-ICING INSTALLATIONS

Information on the thermal, or alternative Goodrich, system is not available at the date of publication.

FIRE EXTINGUISHER SYSTEMS

The separate nacelle installations each comprise a Graviner Mk. 4 6 lb., methyl bromide container, aft of the bulkhead, connected to a six-way junction box on the starboard rear of the engine. Spray pipes from the junction box lead; one across the rear of the engine and through the air scoop to the base of No. 1 cylinder; another forward along the starboard side of the engine round the front and aft to the auxiliary drive casing; a third down to and forward along the induction manifold, then up to the constand speed unit; and a fourth follows this run on the other side of the engine. Another pipe from the box passes to the injector spray nozzle. There are push buttons above the cockpit feathering switches and inertia switches beneath the starboard side of the floor at frame 7. Two flame switches on the starboard side of each engine, one on the port side and one at the bottom of the firewall, are connected to a warning lamp in the appropriate feathering switch.

The cabin heater is protected by a Graviner 27N/53, 1 lb. methyl bromide container, on the aft face of the bulkhead at frame 30, connected to a spray pipe that passes through the heater shroud and encircles the heater. The container is connected to the inertia switches at frame 7 and to two flame switches that project into the heater shroud. Discharge of the container automatically breaks the electrical supply to the heater and its fuel pump.

An anti-fire pistol and spare cartridge is on the port side of the cockpit and there is a Graviner 1½ lb. water/glycol hand extinguisher on the passenger cabin front bulkhead and another in the radio compartment.

(To be concluded)

Professional Publications

Under this heading are given each month the principal articles of aeronautical interest appearing in the current issues of the Journals of the leading Professional Societies and Institutions

The Society of Licensed Aircraft Engineers

THE TECHNICAL INSTRUCTOR (Monthly)
Vol. V, No. 11, November 1950

The Functioning of a Manufacturer's Service Department. A. J. Brant
Servicing the Jetliner

Institute of the Aeronautical Sciences (U.S.A.)

JOURNAL OF THE AERONAUTICAL SCIENCES (Monthly)
Vol. 17, No. 11, November 1950

Lift on Inclined Bodies of Revolution in Hypersonic Flow. G. Grimminger, E. P. Williams and G. B. W. Young
The Longitudinal Stability of Elastic Swept Wings at Supersonic Speed. C. W. Frick and R. S. Chubb
A System for the Excitation of Pure Natural Modes of Complex Structure. R. C. Lewis and D. L. Wrisley
The Flow over a Wedge Profile at Mach Number. I. G. Guderley and H. Yoshihara
Effect of Torsional Stiffener Requirements on Wing Structural Weight. W. R. Micks

AERONAUTICAL ENGINEERING REVIEW (Monthly)
Vol. 9, No. 11, November 1950

The Application of Pressure Refueling to Flight. G. E. Woods-Humphrey
Progress in Stall Research. G. Campbell and G. Bull
Problems Related to Airworthiness Requirements for Commercial Turbine-Engined Aeroplanes. G. W. Maldeman
Current Turboprop Power-Plant Installations. F. H. Sharp

The Royal Aeronautical Society

THE AERONAUTICAL QUARTERLY
Vol. II, Part III, November 1950

Beams on Elastic Supports and on Cross Girders. J. M. Klitchieff
The Estimation of Range of Jet-Propelled Aircraft. H. Pearson
On Non-steady Motion of Slender Bodies. J. W. Miles
The Correction of Wind Tunnel Nozzles for Two-Dimensional Supersonic Flow. R. E. Meyer and M. Holt
Some Developments of Expansion Methods for Solving the Flutter Equations. J. Williams

L'Office National d'Etudes et de Recherches Aéronautiques (France)

LA RECHERCHE AÉRONAUTIQUE (Alternate Months)
No. 18, November-December 1950

Les Essais de fatigue à phusieurs étages. H. Guyot and G. Schimkat
Détermination expérimentale des masses généralisées. G. de Vries
L'influence de la recombinaison sur les performances des fusees. R. Engel and U. T. Boldewat
Le trajectographe O.N.E.R.A. I. Podliasky
Recherches relatives à la couche limite. J. Civrac and M. Sirieix
Détermination de la température moyenne dans une chambre de combustion. L. Viaud
Mesures des moyennes et des différences des pressions. A. Fauquet
Le flutter flexion-torsion en régime plan supersonique. R. Weber and W. Ruppel

The Society of Automotive Engineers (U.S.A.)

S.A.E. JOURNAL (Monthly)
Vol. 58, No. 11, November 1950

Summaries:
A New Concept in Internal Combustion Engine Cooling. R. A. Hundley
The Case for the Turbojet. W. Boyd
Extended Life of Propeller Turbine Engines. R. N. Dorey

Production Engineering, Administration and Management

A Series of Articles Providing a Complete Survey of the Economics of Production for Aeronautical Engineers

By J. V. Connolly, B.E., F.R.Ae.S., M.I.Prod.E.

(*Concluded from p.* 370)

8.0 **The Arts of Production Management**

The whole of the preceding chapters have attempted to show the various components of the ideal manager's knowledge and mental equipment. At the beginning it is seen that separate subjects, hardly related to one another, form a background of general knowledge necessary (or at least highly desirable) for the formation of sound judgments. These are joined by the specific tool subjects, technologies and skills which have a direct bearing on the practice of management. These, in turn, are combined in the field of control, dealt with in chapter 7.0, where perhaps two or more tools, guided by background knowledge, are used to perform certain important controlling functions necessary in the practice of management. It will, however, be clear from a reference to paragraphs 1.10, 1.20 and from TABLE I that all these things are merely part of the manifestations of Management and Administration and not the essence of the functions.

8.10 **Administration.** The essence of Administration is the 'Determination of Objectives and Policies' and the essence of Management is the 'Conversion of these policies into practical results'. It is axiomatic that this should be done in the optimum manner. Both of these functions are at present more arts than sciences. It has been suggested already that the steady trend of events is to diminish the proportion of art, substituting science as the knowledge grows in various fields. The greater the knowledge of the various constituents possessed by a practitioner the easier it will be to arrive at correct answers, the less will purely instructive judgment, guess-work or 'flair' be necessary in reaching a decision. The substitution of systematic knowledge for lengthy empirical 'experience' is the aim of all workers on the theory of these subjects.

8.11 The term 'systematic knowledge' implies two necessary characteristics:

One, that a unique answer can be given to a clear question by the use of theory or classified compilations of facts, such as, for example, a dictionary or a log table.

Two, that the techniques of performing the operations involved in getting the answer can be taught and that they do not depend on chance or instinct to any great extent.

8.12 It is clear that a large number of the subjects mentioned in earlier chapters comply more or less completely with this definition. They are, in any event, not much farther removed from this condition than are Physics, Chemistry, or Botany. In this class would be grouped Law, Statistics, Financial and Dimensional Measurement, some aspects of Economics, and Quality Measurement and the greater part of the technical processes and machine tool operations.

In comparing these subjects with the classical subjects of science, mentioned earlier, there is no implication that nothing more needs to be known, or alternatively that it is an easy or infallible action to get the correct answer, but it can be held that a competent and trained man will, in an overwhelmingly great number of cases, produce correct (or at least satisfactory) answers if he devotes proper care to the problem. After all, that is as much as can be said for any science in its existence state.

8.13 There is another group, including subjects such as Psychology, Physiology, Organization, parts of Economics and Work Measurement, which, although sciences, are under-developed and which cannot yet answer a substantial number of legitimate questions with clarity and precision. It will be an 'art' to select the best answer, or the positive quantitative figure, to use from a band or area of data, possibly of significant width.

8.14 The final group, which includes several most important subjects—probably in some respects the most important—appears at present to be in an unsatisfactory condition. The common assumption is that the position is worse than the facts disclose, and after analysis, a situation emerges which is quite promising for the immediate future.

8.20 **The Common Problem of Management Practices.** The three main subjects in which this situation (8.14) exists are:

8.201 Administration;

8.202 Management;

8.203 Production Design.

8.21 There is one common class of problem at the core of the successful practice of each of these. This can be expressed briefly as follows:

'The correct answer is obtained only by the selection of courses of action (or the choices of alternatives) from a multiplicity of possible alternatives in such a way that the optimum result is attained.'

8.22 This statement of the problem is perfectly general and may seem correspondingly obvious. It will, therefore, require expansion in some detail; it is nevertheless necessary to work from this general theorem if the logic of the process is to be seen.

8.23 First, examining the 'alternatives' or 'courses of action', these may be of the following nature.

8.231 Some may be 'yes' or 'no' (black or white) choices or alternatives.

8.232 Some may appear, at first sight, to be so, but on skilful analysis may divide into several different classes. They may not be real alternatives, or there may be more than two choices (black, grey, or white or even red, white and blue).

8.233 Some may be functions; one value of the choice may vary with time, weight, distance, etc. Such functions may be continuous or discontinuous and they may also be linear or complex; i.e. they may vary directly, or by following some mathematical law involving higher powers, e.g. exponential, cubic etc., without known limits.

8.234 The choices may not be independent. Having made some of the chronologically earlier choices this may limit some or all of the subsequent ones, or the selection of a particular alternative, at any numerical value, may enlarge or diminish other numerical values of remaining choices. Indeed, there may well be a complete dynamic relationship between all the choices (e.g. choosing 'red' may turn all the existing 'blues' into 'purples).'

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(4) The Principles of Organization. J. D. Mooney. (Harper. 1947.)

(5) Specialist Productivity Team Report on 'Management Accountancy'. Anglo-American Council on Productivity. 1950.

8.30 **Problem Solving.** It is clear that with certain possible combinations of circumstances capable of obeying a variety of 'laws' of this nature no general 'theory' is capable of universal application. By no means all real situations contain such a complexity of possible difficulties. There are, on the other hand, real situations which are just as complex as 8.234, where the number of variables is vast, the knowledge of the individual laws they obey is non-existent or scanty and the real relationship between these separate (but not independent variables) is not known at all. When faced with such a problem there are three broad alternatives:

8.301 An instinctive or 'precedented' answer can be given;

8.302 The problem may be simplified by rejecting some of the complexities; preferably those which can be shown to be of a secondary nature. In other words a simplified 'model' can be set up;

8.303 Research can be instituted into each of the variables and their dynamic relationships. This may be possible but will usually take a long time and may lead to enormous cost. The adoption of this plan will clearly be possible only in the most important cases. What is most important is that the individual making decisions should know what is the nature of the choices he makes in reaching a decision.

8.40 **The Basis for Decision Making.** The vast majority of decisions which are made are not at present accompanied by such an analysis. Many of them are on the basis of 'precedent' or, worse, on a 'hunch'. In other cases, where the nature of the business is relatively stable and the surrounding environment has either little effect, or is otherwise easily predictable, 'rules of thumb' are applied. This is akin to para. 8.302, and can range in quality from something little better than a guess to a fairly accurate solution of a representative model.

Some institutions are faced with problems of such magnitude and importance that in varyng degrees they do all that is possible to obtain a unique solution to the problem in all its complexity.

Since this is the ideal method it will be useful to examine it in some detail. Here it should be kept in mind that we are still examining the central problems of three different activities (administration, management and design) in the region of their common similarity. That is to say, in the quality possessed by each of them which demands the same logical method and where there are analogies which differ only in quantitative but not in qualitative relations.

The object of performing any analysis, as we have seen earlier, is to select an ideal, to arrive at the correct solution, or to 'optimize' a result working with the disposable 'means' in the form of data.

8.41 'Optimizing' implies that some particular quality is selected to be made as great as possible consistent with what may be called the 'rules of the game'. These rules may be laws, either of nature or of the State, or they may be less explicit such as satisfactions to individuals or groups. The thing may thus be measured in a variety of units, some precise, such as £ s. d. or weight in pounds, and others in much more abstract terms such as pleasure or comfort. The recognition of the appropriate units may indeed present the major problem.

8.42 Where either the clear recognition of the

units or their quantitative expression is not possible, it is frequently possible to convert them into a more tractable form, by a statistical procedure. Thus 'satisfactions' can sometimes be 'measured' by the amount of money spent by a population on obtaining them, or even by count-in the numbers of people who take advantage of opportunities to indulge them. In this way it is frequently possible to say that a population prefers one type of satisfaction to another in a ratio of 'n to 1', thus obtaining a numerical value for use in equations. This field is that of Market Research and includes 'opinion polls' (commonly called Gallup Polls). The usefulness of this procedure in adminstration is receiving increasing recognition everywhere. Thus, one of the great administrative problems of the past is gradually coming under systematic control.

There are some outstanding difficulties including that of cost, in the extension of this method, and there are still certain problems, which were highly 'spotlighted' by the failure to predict accurately the American Presidential election last year. On the whole, having regard to the inherent difficulties, the process is a most useful tool in this field, and the British Government is finding its use (through the Social Survey) of great assistance. It is also well known that no large marketing campaign is conducted in U.S.A. without consulting this new type of 'oracle'.

8.50 **Mathematical Approaches.** On a small scale, but showing similar promise, is some of the work of the Econometric Society. This particular aspect of the subject is more generalized, using national regional statistics to determine what has been the economic 'choice' of the area in the past and predicting therefrom (after making corrections for items such as changes in available spending power) what will be the behaviour in the future. Experience in these techniques, which are new and difficult, is scanty but the idea is gaining wider acceptance rapidly.

Mention has already been made of Von Neumann and Morgenstern's work, 'The Theory of Games and Economic Behaviour' which, in the few years since its publication, has been used as the background for several important investigations. The final judgment on these new techniques must await much wider application and the correct solution of problems which are otherwise intractable.

It should be remembered that the solution of any problem of this nature depends largely on the availability of statistical material. There is much greater readiness in America to release information of this sort, both financial and that relating to numerical quantities, than there is here. Thus progress will inevitably be more rapid in the U.S.A. and successful applications will certainly occur there earlier if the systems are likely to make a useful contribution.

8.60 **Engineering Economy Analysis.** Apart from the new ideas mentioned above, there is available a most powerful method, the use of which is not so restricted. Engineering Economic Analysis is a fairly widely used method which in its essentials covers the same field. It can be held that Market research, Econometric predicting, etc., are merely extensions of the normal methods used by good designers and administrators, in the solution of everyday problems.

This substitutes, for mere guess-work, an analysis of all the known factors and a systematic assessment of the unknowns (or intangibles) which are not easily quantified. In essence it consists of displaying systematically all the costs and all the returns so that the point of optimum value, from the point of view under consideration, may be clearly seen.

The familiar 'break even' curve for a manufacturing enterprise is a typical example. Here, the fixed and variable costs are plotted separately against quantity produced (or rate of output), etc., and all the curves are added to give a total cost function. This is compared with the expected sales and various 'selling price—quantity' relationships may be derived. See FIG. 22.

In this simple example the guess-work is reduced to the minimum, residing largely in the assessment of the market reactions to various prices or the estimate of the demand for the product.

Good practice in the systematic analysis of all problems of this type is the mainstay of the present competent administrator and there are several excellent textbooks covering this field. It is undoubtedly the most important skill for each of the three subjects under discussion. It can also be applied, to some extent, to the solution of human relations problems, provided that the user is prepared to make a sensible quantitative assessment of the effect of, say, increased wages (bonus or incentives, etc.), or reduced price (or improved service or facilities) on the reactions of the customer or the worker. This means that some statistical or 'experience' data must be selected to give an indication of what effect a percentage change in a variable will have on others. In the absence of special studies—as previously mentioned—this will be an art arising from experience of similar problems.

8.70 **Administrative Decisions.** In all the above discussion the establishment of the basis for arriving at a correct decision have been under consideration. The five aspects of a decision are:

8.701 What is to be done? . . . . Objective
8.702 When shall it be done? . . Timing
8.703 Where shall it be done? . . Place
8.704 Who shall do it? . . . . Organization
8.705 How shall it be done? . . Method

8.71 Each of these questions must be answered satisfactorily by the application of one of the types of systematic analysis mentioned above. Some few administrative, management, and design decisions are largely predetermined by circumstances, customs, laws or rules, but where this is not the case the man who has the **Responsibility** and the **Authority** to make the decision must 'evaluate' the evidence and issue his 'command'.

8.72 The duties of the administrator are not fulfilled unless these two steps are taken. The steps taken in arriving at the data to be evaluated are, in theory, chiefly staff functions (see 1.40 and 8.90), but of course they may in fact be performed by any of the various classes of people in the enterprise; in such cases as a special function apart from the *main* purpose in the Organization. The step of making the 'judgment' and giving the 'Order' releasing the action is the Administrative one.

8.73 **Authority.** The possession and the proper delegation of authority is an essential part of administration.

Authority and Responsibility are inseparable, but this fact is not always fully appreciated, either by the person delegating or the recipient of delegated authority. Before delegating, therefore, an examination of the implications is essential. Both parties should be clear on the full extent of these implications.

There is a tendency for delegates to extend authority without being so readily prepared to accept the associated responsibility. Delegated authority must therefore be expressed in specific terms. Failure to do so will result in either a limitation or an unexpected extension of the delegated authority. Possibly duplicate authority will be set up.

8.74 In the case of delegated authority the higher, and delegating, authority does not avoid its own responsibilities. These are transferred from the performance of the actions to the responsibility for seeing that they have been carried out. Thus, it will usually be necessary to include in the delegation a reporting responsibility to ensure that what is required has been achieved. There are, of course, several degrees of delegation, varying from almost complete representation (or agency with very few limitations) to precisely limited functions controlled by definite and unvarying rules.

Good administration requires the maximum practicable delegation and thus the most carefully considered assessment of the quality of the persons to whom the authority is extended. Apart from the fact that it is usually physically impossible to perform all the actions in an organization, there is the inescapable fact that a primary duty of administration is to think for the future.

8.75 This future planning has two aspects:

1. If the administrator is constantly overloaded he will not have the requisite time to do this imaginative work properly, to study the problems and expand his knowledge of new developments;
2. It is necessary to ensure that replacements of administrative staff are constantly growing up to take the place of older men. Unless the controlled exercise of authority and the development of readiness to accept responsibilities are practised, this cannot occur successfully.

Great faults in this latter process are common. They arise from two chief sources. Firstly, the common reluctance of active and capable men of strong character to envisage clearly the end of their useful life; and secondly the undoubted fact that they can usually (up to the point of severe personal overloading, the onset of which is insidious) do the job better, quicker, and with less irritating explanation than their juniors.

Nevertheless, both good administration and management demand discipline in this matter and a constant check of the position by the governing authority is a clear duty in the interests of the enterprise. It is, however, a very difficult matter to enforce successfully.

8.76 In the foregoing sections it has been demonstrated that the duties of Administration are:

8.761 To analyse and decide;
8.762 To plan, organize and co-ordinate;
8.763 To control, which includes appraisal and

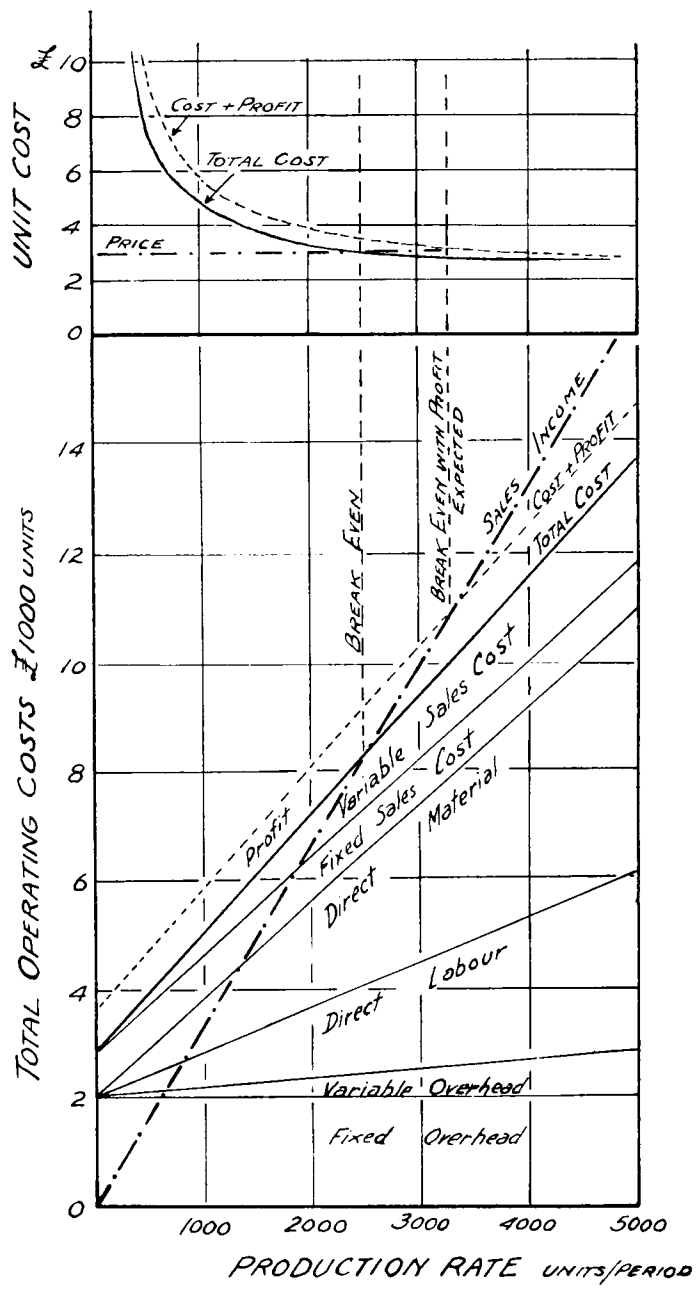


Fig. 22.—A Simple Linear Break-Even Chart

This shows the quantity which must be produced for any given selling price or any similar parameters in the relationship. These curves are not always linear in practical cases

correction. Some of the requirements and methods have been discussed in detail.

In general it can be seen that, from a theoretical point of view, most of the activities can be almost mechanical and objective. No emphasis has been placed on the human qualities such as leadership, respect, or confidence. Since the Administration has to deal with people, in the form of Managers, these qualities are necessary to some extent in that they will affect relations at this level. Nevertheless the primary requirement is the ability and judgment to perform 8.761 to 8.763 competently.

8.80 **Management.** As we have previously observed, Management is concerned with getting things done. The function is an executive one and, in so far as policy determination occurs, it is incidental and not fundamental. This definition is not invalidated by the fact that many managers are also concerned, *inter alia*, with some aspects of administration. They are then performing a different function, so to speak, and are acting in a different capacity.

Gettings things done is very nearly synonymous with getting people to do things, and it is therefore quite clear that the intangible factors have considerable importance. Regardless of the ultimate correctness of the policy a good manager will be able to carry it out. He will not necessarily be a worse manager (and, indeed, he may show himself to be a better one) if he has to perform a task which has not the initial instinctive support of his subordinates. Without going so far as to say that the executive function has no concern with the formulation of policy, it can, and must be, carried out loyally even in the face of personal disagreement with the administrative decision. This is, of course, within limits of conscience and profound conviction.

To produce such a conflicting situation may well be a manifestation of bad administration but not necessarily so.

8.81 It can be accepted, therefore, that a good manager must possess the following qualities, as a minimum:

8.811 A technical knowledge of the job adequate to interpret policy into terms of positive action;

8.812 Capacity for leading his subordinates;

8.813 Personal qualities and training which enable him to Co-ordinate—Control—Compare—Appraise.

It can be seen that these are somewhat different from the essentials for an administrator. Administrative and executive qualifications may be possessed by one man, but not necessarily so. In other words a man may be a good 'leader' but a bad 'decider'.

8.82 It follows from paragraph 8.81 that a Manager when he is performing his executive functions must:

8.821 **Prepare** to accomplish the job, by:

Analysing the requirements of the policy;

Systematizing the procedures;

Designing the details of the co-ordinating and control system, appropriate for the above procedures.

8.822 **Release action** or command by:

Issuing orders and instructions;

Enforcing discipline while the action proceeds;

Operating the central control by making choices rendered necessary by the information provided by control;

Supervising the progress against the plan and deciding the point at which success, in accordance with policy, has been attained.

8.823 **Review** the operations at the completion of the job by:

Collecting and reviewing the necessary statistics and data;

Passing the results to higher authority;

Recording, for future improvement, any knowledge gained.

These three main cycles are repeated at all levels of management and differ in scope and nature according to the level. The principles remain the same, however, whether at General Manager's or Foreman's status.

Some portions of these cycles have a similarity with administrative processes and can be roughly described as 'micro-administration'. The dynamic nature of this process is of importance but requires lengthy treatment for which study of the textbooks is needed.

The necessity for knowledge of many of the tools of management will be apparent. In the higher levels of this process, it is necessary for the systems and controls to be designed to effect the policy of the enterprise. This must be appropriate to the problems.

The constant making of detailed decisions also requires a good knowledge of the legal, physiological, and psychological restraints operating against successful attainment of the parts of the plan.

It is not essential, and it is frequently impossible, for all the specialized knowledge to be found in one man, who has also the special qualities mentioned in 8.812 and 8.813. In the absence of such knowledge it must be made available to a man with these qualities by a staff.

8.90 **Staff.** The function of a staff is to advise, and to assist by the collection and analysis of data (see also 1.40). When acting in a staff capacity, the individual has not administrative or executive duties or responsibilities. He may have such functions within his own department, i.e. in relation to his own staff, if any. He will not function in the chain of authority which operates the enterprise. A specialist in any subject may be utilized to assist any executive or administrator. It is obviously possible also to use executives possessing specialist knowledge in a staff capacity on occasions when their other duties permit.

The staff principle is used extensively in large organizations such as the army, the church and certain complex industrial organizations.

9.0 **Conclusion**

No attempt has been made in this series of articles to produce a textbook dealing with the formal theory or practice of any of the many aspects of administration and management. Bibliographies have been given, which will enable these theories to be studied. An attempt has been made to survey the relationships and describe the working of the system of Industrial Management. Some indication of the author's opinions on the direction which events will take in the future are also included.

Reference has been made to a large number of authorities, but acknowledgments for the help and opinions accepted from them is not practicable and there are many textbooks additional to those mentioned which have gone towards the formulation of the author's ideas, which are his personal responsibility.

Book Review

The Latest Jane's

Jane's All the World's Aircraft, 1950-1951. Compiled and edited by Leonard Bridgman. [Sampson Low Marston, £3 3*s*.]

One's inevitable task is each year to review *Jane's*—when it appears. In the 'twenties and 'thirties it arrived late in the year in comfortable time to form a prelude to the New Year—and to make a suitable choice for relatives in search of a seasonable gift. During the war production difficulties and enemy action played havoc with the schedule and since the war it has appeared in September or October, double-dated for the current and the following year. Because it arrives at this season, when there is a spate of releases of new aircraft concurrently with the holding of the S.B.A.C. Display, it always has to be supplied with an addendum—loose with the first copies and bound into the beginning with later ones. As a user of *Jane's* one would plead for a different publication date so that this inconvenient expedient could be avoided.

Before reviewing the contents we must reluctantly make one further complaint about this year's edition and that is the poor quality of many of the halftone illustrations, apparently due to an excessive amount of dressing in the art paper.

One has already become so accustomed to the three-column make-up that recently an earlier edition seemed quite strange when consulted. The two-column layout has been retained for the engine section (where it is obviously more convenient because of the length of some of the individual descriptions and because of the more suitable block sizes) and for the reintroduced Airship, Section E, which has been absent since 1940. The contents of all sections are remarkably complete and up to date on the whole and, as usual, there are many new illustrations and much revised text. The new feature, a list of first flights made between June 1, 1949, and May 31, 1950, is a useful one, even though it is one that security restrictions must necessarily render incomplete. The inclusion, too, in the individual descriptions of first flight dates is also a feature that we often find useful. In this respect, where brief histories of prototypes are also included it seems rather mealy-mouthed rigidly to avoid mentioning dates upon which prototypes have been destroyed—in at least two cases the test pilots connected with the aircraft reviewed are mentioned—as, in a work of reference, these facts can sometimes be of use. It was impossible to check data exhaustively, but a number of 'spot-checks' failed to reveal many examples of those irritating misprints, particularly in metric conversions, of which we complained last year. In the Aeroplane, Section C, there are many general arrangement drawings, one is glad to note, which although small are accurate—even in the case of one which, the manufacturer assures us, must be unofficial because no drawing is allowed by security! On this subject, it was a very good effort to include drawings of the Saro Duchess, the Avro Ashton and the Airspeed A.S.67 in view of the press date. The majority of the new American types, too, are shown in drawing form; but France is rather neglected in this respect, although well covered photographically. More sectioned drawings of jet engines would have been very welcome—but probably rather an uneconomical proposition.

Finally, we must conclude as always with the remark that *Jane's* is the best aeronautical value for money of the year.

A TRADE REVIEW

Nimonic 90

Aluminium Alloy Castings Containing Nickel

[The Mond Nickel Co. Ltd., Curzon Street, London, W.1]

The first of these publications deals with a new nickel alloy that has been under trial for gas-turbine components. Nimonic 90 is a wrought alloy which may be operated at higher temperatures than the well-known Nimonic 80A. This brochure gives in a clear, practical manner all the necessary data about its properties, together with creep-stress diagrams and notes on forging and heat treatment.

The second booklet is a comprehensive thirty-six page illustrated treatise on the effect of nickel in light alloy castings. The subject is dealt with fully from both the metallurgical and production aspects. A useful list of references is also included.

The T.W.A. Overhaul and Maintenance System

A Note on Some Aspects of the Organization Developed by a Major U.S. Airline

By H. W. Perry

DEVELOPMENT of the Kansas City base of Transcontinental and Western Air has been proceeding since 1946, in which year the wartime Army-operated modification centre in the city for B-25 bombers and Constellations was leased from the Reconstruction Finance Corporation and converted to peacetime use at a cost of $1,000,000. The hangars, shop and office buildings enclose a combined area of 427,000 square feet and are surrounded by more than 1,000,000 square feet of concrete ramp or apron. The hangars are fitted to accommodate at the same time three Constellations and eight Stratocruisers, DC-4's or DC-3's. Nearly 2,000 men and women are employed at the base.

By the spring of 1949 the new overhaul base was working under the direction of R. M. Dunn, Director of Engineering and Maintenance, and the supervision of John A. Collins, T.W.A. director and Vice-president in charge of operations, with Frank Busch as General Operations Manager. The writer is particularly indebted to Mr Dunn and his engineering staff for supplying the information contained in this article.

Location and Layout

The T.W.A. fleet will, by the end of 1950, include 55 Constellations, 71 DC-3's, 12 DC-4's, 5 Stratocruisers, and 12 Martin 2-0-2's, leased for use pending deliveries of 30 Martin 4-0-4's.

The Kansas City base is located at Fairfax Airport on the Kansas side of the Missouri River, which divides that State from the State of Missouri. On the opposite side of the river is the Municipal Airport and Terminal for all air traffic into and out of Kansas City, Mo.

Aircraft in service are flown into the terminal on regular passenger schedules. As those on international services generally operate between New York City and overseas destinations, near the time for periodic maintenance they are diverted into the domestic flight schedule or are used as extra flight sections into the Terminal. From there the transports scheduled for overhaul or modification are ferried across the river to the Fairfax base. After completion of the operation they undergo a flight test which usually ends at the Municipal Airport, where any minor corrections needed are made and the aircraft are again ready for service.

The two large wooden hangars are divided into four-bay areas, a parts store located between the two bays in one hangar being connected by short tunnels or aisles with the two bays in the adjoining hangar.

Much newly developed equipment installed at the base includes work docks (FIG. 2) for the Constellations and the DC-4, which have reduced by $1,500 the cost of each major inspection. Electric light, power and compressed air are laid on to the docks.

Another major new item of equipment is a mechanical engine-parts washer in which parts stacked in wire baskets or hung on hooks from an overhead conveyor move through an eight-stage sequence of chemical baths in a 300-foot-long tunnel during a nine-hour period. This washer, with the attention of only three men, does the work of a crew of forty using the old vat cleaning method—and does it more thoroughly.

Engineering Department Organization

In the accompanying chart (TABLE I) is shown the general organization of the engineering and maintenance department. Last spring the department had an assigned strength of 1,467 personnel, including 1,000 line maintenance employees and supervisors in the domestic system and 260 employees and supervisors in the international system which had 37 Americans overseas.

Inspection Section. This is responsible for quality control of all T.W.A. aircraft and is under the direction of a manager with headquarters at the Kansas City overhaul base. A chief of inspection at each of three major line maintenance bases directs the inspection work assigned to his base and is solely responsible for quality control there. If agreement regarding a specific type of repair cannot be reached at a line base, the case is referred to the manager of inspection at Kansas City. As a decision of the chief inspector at a base cannot be overridden there, this assignment of responsbility is believed by the airline to assure the maintenance of maximum airworthiness of craft everywhere on the system.

Planning Section. Duties of this section are continuously to study and analyse current methods and costs and recommend changes or develop new programmes to effect more efficient operation and economy, with the object of keeping the base abreast of advancement in methods of maintenance and overhaul of modern air transport equipment plus striving for improvement of the art.

Production Control Section. This reganization schedules and controls overhaul work done on aircraft while in the hangars and work performed in the shop. A hangar production control group has full responsibility for planning and scheduling all modification work, which usually is done while aircraft are undergoing routine overhaul. It also prepares and issues work and inspection forms, work-sequence charts, drawings and instructions for modifications.

Work-control clerks, who report to this group while aircraft are undergoing overhaul, keep all paper records current to ensure that work schedule is accomplished and signed for by the mechanics. They help the foremen in assigning manpower to assure minimum overhaul time and keep a current record of the state of work on the work-sequence charts.

Like the hangar production group, a shop production group schedules all work done in the shop, consisting of overhaul, repair or manufacture of component units and parts needed in overhauling of craft at Kansas City and also maintaining them between overhauls. A highly important function is the scheduling of shop work on units received from stations along T.W.A. routes for reconditioning and return, so as to have serviceable parts always available at the stations to avoid long delays of transports and yet not have an over-supply involving a waste of work time and materials.

To accomplish this, the group keeps currently posted a record of the supply of serviceable and unserviceable units in the entire airline system, and provides means for their quick movement between the several line stations and the overhaul base and between the various sections within the base itself, thus reducing the repaired units on hand to the lowest possible number consistent with operating requirements of the airline system.

Besides the two groups mentioned above, the production control section includes a maintenance analysis group and a maintenance manual group. The former keeps records of unit failures and malfunctioning and prepares reports and analyses indicating action to be taken to correct the functioning or to reduce incipient troubles to a minimum. The maintenance manual group compiles information regarding approved maintenance methods and distributes it throughout the T.W.A. system for the use of the mechanical personnel.

Overhaul Section. To this is delegated the overhaul, modification and repair of aircraft, components and accessories. It is composed of the following eight shop groups:

Engine Build-up and Fabrication, which works on engines, paint jobs, upholstery and fleet cleaning.

Fig. 1.—A general view of the Transcontinental and Western Air Lines terminal overhaul base at Kansas City

Engine Overhaul, in charge of engine production, machine shop and engine testing.
Radio and Electrical.
Sheet Metal and Aircraft.
Accessories.
Propeller.
Instrument.

Hangar Production, consisting only of supervisors, who have charge of the overhaul base hangars. This group obtains the most effective and efficient use of manpower by assigning only foremen to the bays and all mechanics to specialities in the shop as classified above. Each foreman is held responsible for the accomplishment of the overhaul of the aircraft assigned to him. 'Speciality men' are called from the shop as needed and are under the direction of the foremen while in the hangar. When a man is no longer required there in connexion with his speciality he is returned to the shop.

Engineering Section. This organization is responsible for designing all modifications of aircraft and associated equipment and for providing any technical assistance needed in connexion with problems of aircraft operation, maintenance, or overhaul. It consists of four groups, each headed by a superintendent under the direction of the section manager. Technical problems associated with certain aircraft parts or equipment are referred, according to type, to one of three groups designated:

Mechanical engineering,
Radio, electrical and instrument engineering,
Structures, equipment and materials engineering.

In this organizational set-up of the engineering section no consideration was given to the fact that T.W.A. operates aircraft of several types. It was chosen in preference to a breakdown based on responsibility for overhaul of individual plane types because:

(*i*) It makes possible a higher degree of specialization.

(*ii*) Consistency in dealing with problems common to all aircraft types is more probable.

(*iii*) Organizational stability is maintained because the addition of aircraft types to the fleet (or their removal from it) does not affect the number of engineering groups or the assignments to individual speciality engineers.

The fourth group in the engineering section is named Operational Engineering and is composed of two engineers, three pilots and a flight engineer. To it are assigned: liaison between the engineering and maintenance sections and the flight operations department; production test-flying of all overhauled craft; analysis and preparation of flight operational procedures; weight control; development of cruise-control data for each type of aircraft to obtain maximum payloads consistent with safe operation; and conduct of flight tests and making analyses therefrom of the performance of each type of aircraft.

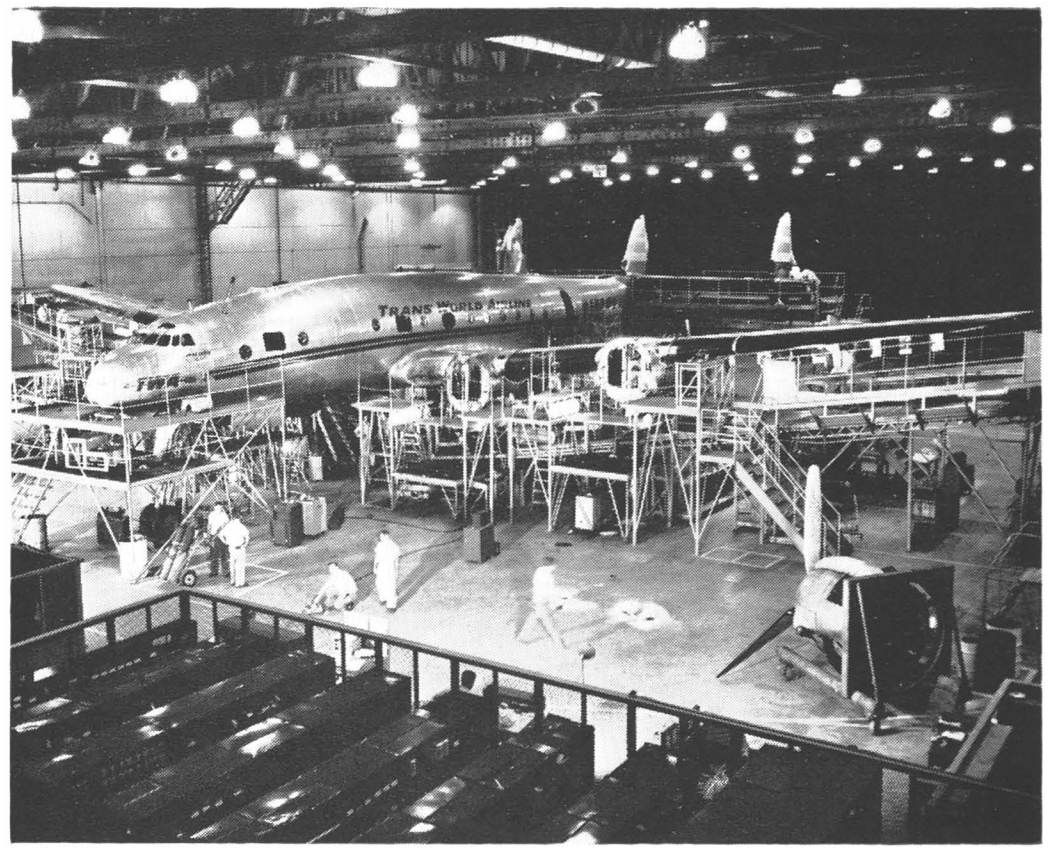


Fig. 2.—Typical of the docks in use at the T.W.A. Kansas City base is this one for a Lockheed Constellation

Line Maintenance. The manager of this section is assisted at the overhaul base by two superintendents of line maintenance, one for domestic routes and the other for international routes. There is also at the base a regional operations manager to whom four regional superintendents report. The latter are directly responsible for maintenance activities within their regions. This regional organization is necessary as there must be close integration of the various operational functions in the field, such as flight control and passenger service.

The line maintenance staff has assigned to it manifold responsibilities. They monitor daily operation of the airline, study mechanical malfunctioning and take any action necessary to keep the line aircraft functioning at peak mechanical efficiency. They see that adequate information covering methods of maintenance of the various aircraft and system is published and supplied to all maintenance stations and that it is promptly revised to include any changes. They keep the engineering and overhaul departments informed regarding any chronic malfunctioning which occurs on each type and follow through with these departments until corrections have been made. They establish maintenance methods and procedures for performing the required work most efficiently consistent with safe airline operation. Finally, they are responsible for ensuring that line stations and maintenance terminals are provided with ramp and shop equipment for most efficient performance of aircraft maintenance.

Director—Engineering and Maintenance—R. M. Dunn

Assistant to Director Engineering and Maintenance F. A. Humphrey

Supt. of Ground and Maintenance	**Administrative Assistant**	**Administrator C.A.A. Liaison**
Maintenance of equipment and facilities	General administrative assistance and supervision of Central File & Reproduction Units	Co-ordination of all maintenance activity with C.A.A.

TABLE I—ENGINEERING AND MAINTENANCE ORGANIZATION

Manager Inspection	**Manager Planning**	**Manager Production Control**	**Manager Overhaul**	**Manager Engineering**	**Manager Line Maintenance**
Airworthiness of all aircraft. Audit work of overhaul section. Direct responsibility of all inspection for entire system	Develop and provide long-range plans for Director and Dept. Review practices, procedures and establish standards. Develop methods, budgets, research and planning as required. Provide janitorial, fire protection and plant protection services	Schedule and control flow of work to hangars and shops consistent with limits of manpower forecasts and budgets based on workload. Maintain records and reports of unit failures and malfunctioning. Publication of Maintenance Manuals	Modification, major overhaul and repair of aircraft and associated components	Design of all modifications to aircraft and associated equipment. Furnish technical assistance as required in handling maintenance, operational, and overhaul problems	Formulate the Line Maintenance policies; act as liaison between maintenance stations and various sections of overhaul base; continuously audit system operation to improve handling of mechanical delays and maintenance of highest standards of mechanical efficiency

Methods of Time and Work Control

Maintenance and overhaul work is segregated into related classes and is designated serially as operations 1, 2, 3, and so on. For example, operation 5 consists of changing all four engines and other 'hour-lifed' units that may be due for overhaul; operation 10 is the major structural overhaul of the DC-3. The various operations are performed regularly at the end of the flight operating periods approved by the Civil Aeronautics Administration and shown in TABLE II.

Operations 1, 2, and 3 are performed on international equipment (Constellation 749A and DC-4) at La Guardia airport; on domestic transports (Constellation 749 and 049) at Los Angeles, and on the DC-3 and the Boeing Stratoliner at Kansas City. In addition, a large amount of turn-round maintenance is done at major line stations, such as those at Newark, N.J., Pittsburgh, Chicago and San Francisco.

Insertion in the time-control table of the column 'Engine Overhaul Period' represents an experimental separation of engine change in the case of the 049 Constellation from other overhaul work known as operation 5. This involves the time staggering of engines so that they will be due singly for removal in operation 3. The engineering department believes that, since engine operation time governs their overhaul periods, this experiment will, if successful, 'make possible much greater utilization'.

Incidentally, T.W.A. gives much credit for the considerable increase in approved aircraft operation periods between overhauls in the last two years to co-operation of C.A.A. personnel with the airline and to the International Association of Machinists, bargaining agency for the mechanical, inspection and stores personnel employed over the entire system.

A consolidated list of unit overhaul periods prepared by the engineering department gives elapsed hours between overhauls of all items on the seven types of transports in the airline's service. The periods for many items range between 1,000 and 6,000 hours.

Time-Control Staff and System*

The time-control organization consists of a central staff and six shop time-

* Usually 'hour-lifed' in English—EDITOR.

TABLE II—TIME CONTROL OF MAINTENANCE OPERATIONS

Aircraft	Engines	Op. 1 Flying hours	Op. 2	Op. 3	Op. 5	Engine Overhaul	Op. 10
DC-3 ...	... {Wright G-202A / Pratt & Whitney R-1830}	85	155	310	1,500	1,500	10,000
Boeing 307	... Wright G-205A	85	155	310	1,350	1,350	—
C-54 ...	... P. & W. R-2000	85	215	360	1,400	1,400	—
LAC-049	... Wright 745C 18BA-3	85	215	360	1,500	1,100	—
LAC-749	... Wright 745C 18BD-1	85	215	360	1,300	1,300	—
LAC-749A	... Wright 745C 18BD-1	85	215	360	1,300	1,300	—

control centres. The central staff reports to the supervisor of shop-production control, but has no authority over shop time-control operation. Personnel of the six shop time-control centres maintain a file of record cards of all components currently required on each aircraft. A card for a specific item may be in an aeroplane file, a shop file, or a stock file. The plane file contains record cards of all components currently installed, cards of previously installed components from the time of their removal from the craft until they are received in the shop. Then the record cards of components to be overhauled are transferred to the shop file and held there until the units have been put in proper functioning condition and moved to stock, whereupon the cards are place in the stock file.

A mechanic installing a serviceable time-controlled component on a plane fills in the installation record on the back of a yellow tag and return the tag to the overhaul base. These tags of completed installation are distributed by the time-control staff to the proper shops so that the installation can be recorded on component record cards in the stock file and the station data on the tags checked for agreement with data previously posted. The clerk then refers to aircraft total-time sheets furnished by the central time-control staff and computes the total time of each component on the aircraft and the date of installation, then he enters this time in the 'installed plane time' column of the time sheet.

Next he computes the time when the component should be removed (by adding overhaul-period hours to time of installation) and enters this removal time on the component card, placing the card in the file for the particular plane involved and destroying the shop 'serviceable' tag.

There is also a green 'not serviceable' tag, which the mechanic fills in with record data and attaches to any component he removes from a plane. This tag remains with the item until it is delivered to the shop. When the time clerk receives this tag he checks the location or position data on it against the component record card in the aeroplane file and transcribes to it the date and reason for removal. From the aircraft total-time sheets he computes the total time of the component on the plane and the date of removal, entering these on the time sheets. The not-serviceable tag is then forwarded to the time-control clerk and the unit record card is placed in the shop file.

The shop mechanic who completes the work on the component enters his findings, remarks and the work performed, together with the date on the back of the tag. When the inspector approves the overhauled item he signs the tag and sends it to the time clerk. The clerk enters on the component record card in the shop file the code letters for work performed (O—overhaul, R—repaired, I—intermediate inspection, T—tested, SC—shop checked, Op 3—operation 3); also the date and mechanic's number, findings and remarks, and files the tag, which is then held for two years as an overhaul record of that component.

The foregoing recordings complete the processing of the record card of a component for one overhaul cycle and the card, bearing T.W.A. stock and serial numbers, is placed in the stock file.

Work-Control Programme

The advent of larger and more complex aircraft involving large capital outlay necessitated the development of a system whereby maintenance and overhaul operations could be accomplished economically within a minimum time so as to improve utilization. The programme evolved after months of study and put into effect at the Kansas City overhaul base and the major line stations has aided substantially in improving the quality of the work and also in reducing costs. It embraces the following four factors which are essential to its efficient operation and success: plan, material and parts, equipment and personnel.

Plan. This has four phases: incoming time (line); pre-cleaning and pre-inspection; hangar work, and outgoing time (line). The plan establishes for each phase the number of personnel required for each speciality, the sequence of work, elapsed time for each job, and over-all elapsed time for the phase.

Work to be done on each aircraft is shown graphically on a large chart (FIG. 3) beside the foreman's desk near the aircraft. Names of the parts, such as individual nacelles and engines, right and left wings, tail, cockpit, radio and galley, which are designated as specialities, are printed in the left column. In succeeding vertical columns are shown the load of work to be done on the aircraft, manhours required and elapsed time allotted for each job, and the area loading.

Work represented on the chart is indicated on work-control cards for the various specialities and work areas. These cards, which define the work to be done, are arranged in a specially designed rack table (FIG. 4) in front of the foreman, and are issued to mechanics assigned to the jobs, who sign and return the cards to the foreman when they complete their work.

A work-control clerk relieves the foreman of detailed planning by keeping current the planning chart and work-control cards, informing the foreman of any jobs that are behind schedule, and aiding in co-ordinating the work of lead mechanics and inspectors so that the work will be accomplished in the allotted time. Thus the foreman can determine at any time, from the elapsed time periods shown on the plan chart, what work has been completed, what remains to be done, and what is behind schedule.

Material and Parts. Those needed for an overhaul and maintenance operation are known at the base in advance of arrival of the transport and are assembled in a parts allocation centre adjacent to the aircraft dock, thus avoiding delays or excessive man-hours of mechanics.

Equipment. All equipment needed for operations at the dock, plus other equipment that decreases elapsed operational time, has been provided and is readily obtainable from cabinets located close to the craft.

Personnel. Determination of the number of personnel required for each operation is a very

(*Concluded on p.* 27)

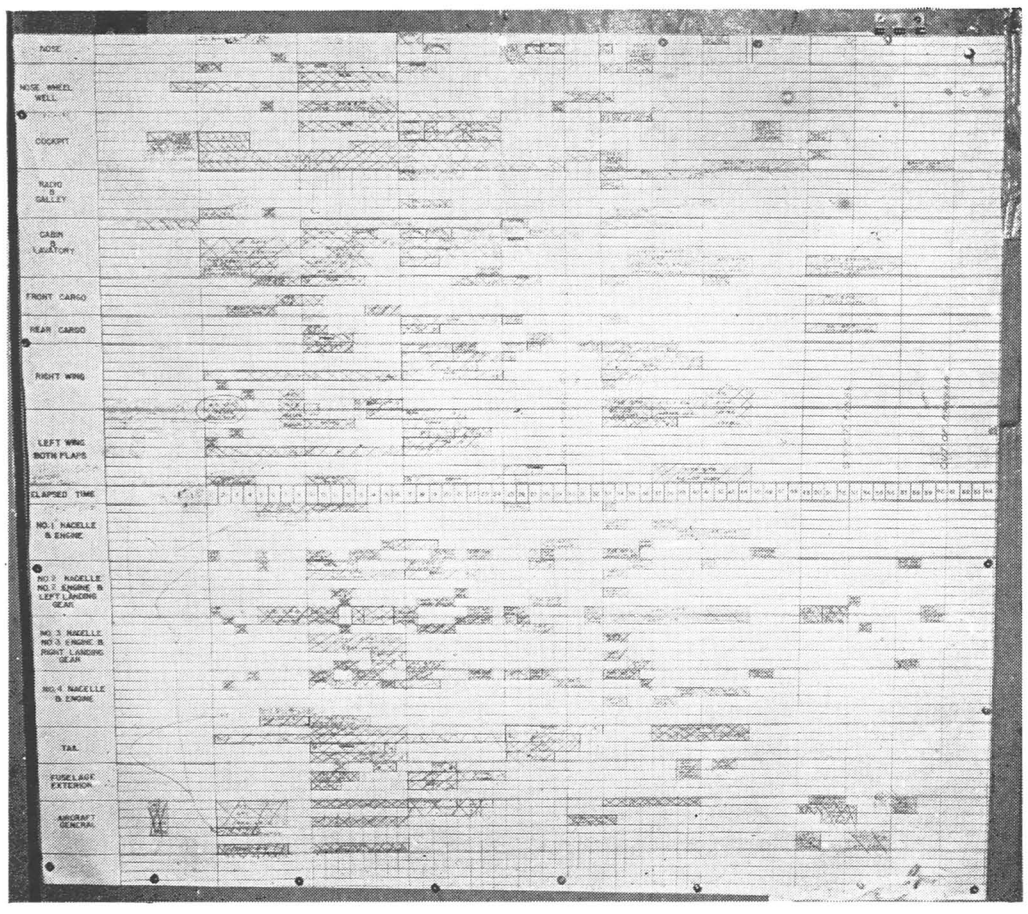


Fig. 3.—Foreman's work and location chart for the work-control programme

Fig. 4.—Work-control cards in the foreman's desk rack. Note the microphone for use in direct hangar control

Research Reports and Memoranda

Under this heading are published regularly abstracts of all Reports and Memoranda of the Aeronautical Research Council, Reports and Tcchical Memoranda of the United States National Advisory Committee for Aeronautics and publications of other similar Research Bodies as issued

CANADA

NATIONAL RESEARCH COUNCIL
Ottawa

DIVISION OF MECHANICAL ENGINEERING SUPERSONICS AND GAS DYNAMICS SECTION

Report No. MT-13. June 2, 1950. A Method of Estimating Optimum Turbine Operating Conditions for a Range of Nozzle and Blade Angles. By E. Duncombe.

A study of previous turbine cascade results enables a summarized chart of optimum performance which can be expected from nozzles and blades to give prescribed gas angles to be developed.

A stage-by-stage method of calculating turbine characteristics for compressible flow is then introduced, which is flexible enough to cater for off-design-point nozzle and blade efficiencies and enables a study of the effects of nozzle and blade choking conditions to be made.

This method is used to show the effects of varying nozzle and blade geometry on the optimum isentropic efficiency and work obtainable from a single stage without flare.

FRANCE

PUBLICATIONS SCIENTIFIQUES ET TECHNIQUES DU MINISTERE DE L'AIR

Magasin C.T.O., 2 Rue de la Porte d'Issy, Paris (Ve).

NOTES TECHNIQUES

N.T. 34. Recherches sur l'Osmose Électrique. (Investigation on Electrical Osmosis.) By L. H. Collet.

The author contends that the theory of the double layer which led physicists to use the phenomenon of electric osmosis for the determination of the charge between solid and liquid phases must be abandoned. He has established the basis for an experimental study of the phenomenon and developed new techniques which promise good quantitative results. Without introducing concepts of a hypotherical nature, he develops a theory of electric osmosis which presents the phenomenon as the manifestation of other phenomenon, already understood.

N.T. 35. Le Point Astronomique Simplifié dans les Régions Polaires. (Simplified Astronomical Position Finding in the Polar Regions.) By P. Hugon. (200 francs.)

The method described allows the base line to be plotted after the reading of a three-entry table within the limits of a colatitude of 10 deg. It is particularly suitable for aerial navigation owing to its speed in use, and does not for go either maritime precision or the use of intercepts beyond 30 miles. The tables given are taken from the English 'Special Polar Air Chart'. The method is illustrated by two examples.

N.T. 36. Abrégé de la Théorie Générale des Séries Divergentes dite Théorie des Séries Définissables. (Outline of the General Theory of the Divergent Series known as the Theory of Definable Series.) By P. Vernotte. (250 francs.)

The author suggests that the divergent series have not yet become classical in their use but will become so. The object of this survey, which covers a wide field and contains several examples, is to show how the divergent series differ from the convergent series, why their use will become important, and how they may be applied.

RAPPORTS

No. 236. Contribution à l'Emploi des Méthodes Optiques en Métallographie Microscopique. (Contribution to the Use of Optical Methods in Microscopic Metallography.) By T. Cambon.

A theoretical study of optical methods for the examination of polished anisotropic sections both for crystallographic research and for the determination of opaque crystals. The second part deals with the techniques developed under the headings: determination of optical characteristics of anisotropy, determination of reflecting powers and the preparation of specimens. The third part describes the application to bronzes, copper-antimony alloys and several silicides.

No. 237. Les Théories de la Turbulence. (Theories of Turbulence.) By L. Agostini and J. Bass.

The first chapter gives a precise and elementary definition of turbulence and describes the methods of mathematical statistics on which later developments are based. The second is devoted to the kinematics of aleatory media, especially isotropic media, while the third is a mathematical study of the application of the Navier equations to turbulent motion. Chapters IV and V explain the new physical theories, including the hypotheses of similitude and leading to numerical laws. The work of Kolmogoroff, Weizsacker, Heisenberg, Batchelor and Townsend is summarized. Some examples of correlation curves and spectral curves, measured by Favre in a wind-tunnel are given in an appendix.

No. 239. Étude de Matériaux à Grand Amortissement. Liège et Caoutchouc. (Study of Materials Having Good Damping Properties. Cork and Rubber.) By A. Brodeau.

Discusses the choice of the type of deformation used for the study of internal friction, the justification of the choice of cork and rubber as materials, a study of abstract solid bodies, the elastic deformations of cork and rubber, the propagation of shock in these materials and their damping properties.

No. 240. Contribution à l'Étude des Réactions Mutuelles des Cristaux dans la Déformation des Métaux Polycristallins. (Contribution to the Study of the Reactions of Crystals in the Deformation of Polycrystalline Metals.) By R. Michaud.

After a note on the mode of deformation of a single crystal of aluminium, this work consists of (1) a study, by Krays, of the influence of the boundaries on the mode of deformation, considering simple (longitudinal and transverse) and multiple boundaries, (2) an X-ray study of the influence of the size of the crystals on the mode of deformation, with the object of determining the transition between the behaviour of test-pieces consisting of a few large crystals and those consisting of the industrial, polycrystalline metals, (3) a study of the distribution of the deformation along a tensile test-piece using a special X-ray technique covering a length sufficient to include several crystals, and (4) a direct measurement of the distribution of the elongations leading to a recording of distribution curves relating to more and more complex boundary configurations.

No. 241. Étude de la Structure des Surfaces. (Study of the Structure of Surfaces.) By G. Blet.

It is shown that optical methods, photographic or photometric, allow a rapid and simple determination of the directions and orientations of the facets produced during the machining and finishing operations on cylindrical surfaces. The methods are applicable to whole surfaces as well as to small elements of such surfaces. In the second part concerning rough surfaces, the author studies the diffusing properties of macroscopic cavities and compares certain surfaces with a juxtaposition of cavities of defined shape.

No. 242. Equations Intégrales et Transformation de Laplace. (Intergal Equations and the Laplace Transformation.) By M. Parodi. (800 francs.)

The fundamental principles of symbolic calculations are indicated and the form is defined which the nucleus must take of certain equations of which the range of integration extends from 0 to $+\omega$ so that the symbolic method may be applied. A study is made of two types of integral equations with fixed limits not necessarily nil or infinity, and analogies are indicated with the Volterra equations. The author demonstrates how the symbolic sequences may be used to solve certain equations. Finally it is shown, with examples, how consideration of functional equations of which the solutions are known permits the construction of integral equations which are their image and how to solve them.

OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AERONAUTIQUES

3 Rue Léon Bonnat, Paris

PUBLICATIONS

No. 41. Table des Coefficients Aérodynamiques Instationnaires Régime Plan Supersonique. Part 1. Exposé Sommaire de la Méthode de L. Schwartz et Introduction aux Tables. (Table of Non-Stationary Aerodynamic Coefficients. Plane Supersonic Conditions. Part 1. Brief Explanation of Method and Introduction to the Tables.) By R. Weber.

This first part gives a short survey of the Schwarz method for the determination of the non-stationary aeronynamic forces and moments acting on an aerofoil section in harmonic vibratory motion and its applicaton to the linear motion of an aerofoil provided with a control surface and an auxiliary control (tab., etc.). An introduction is given to the tables showing how the coefficients must be applied to various stability calculations and particularly to flutter.

No. 42. Les Calculs Matriciel and Spinoriel. (Matrical and Spinorial Calculations.) By J. M. Souriau.

A demonstration of the usefulness of these methods. The author discusses simple and multiple operators, linear operators, columns and matrices, multilinear operators in columns, anti-symmetrical multilinear operators, the theory of determinants and various applications.

No. 43. Essai de Justification d'une Détermination Dynamique de Fréquences et Fonctions Propres Associées d'un Avion et d'un Calcul des Masses et des Rigidités Generalisées Correspondantes. (Justification of a Dynamic Determination of Frequencies and Associated Proper Functions of an Aircraft, and of a Calculation of the Corresponding Generalized Masses and Rigidities.) By A. Schindler.

The author defines the hypotheses underlying a dynamic method of determination of the frequencies and associated proper functions of an aircraft, and a calculation, using weight analysis figures of the corresponding generalized masses and rigidities. He then shows that this dynamic method would give these generalized masses and rigidities, without the weight analysis, if the theoretical bases were physically acceptable and if the practical realization were in sufficient agreement with the theory. The method is then examined from these two points of view.

No. 44. Ailes à Fente—Biplans, Interaction—Sol Calculs et Applications. (Biplane Slotted Wings, Ground Effect. Calculation and Application.) By P. Schmitt.

The first part of this report deals with the calculation of the flow potential about two unequal circles with different circulations, the Lagally potential for the flow about two circles and the conformal transformation of two circles into two aerofoil sections in the same plane. The second deals with the following numerical examples which afford a comparison of the experimental results with the theory; wing with leading edge slot, biplane of two equal wings, ground-effect, wing with slotted trailing-edge flap. An appendix refers to the calculation of certain elliptical functions used in the first part.

NETHERLANDS

NATIONAAL LUCHTIVAARTLABORATORIUM

Sloterweg 145, Amsterdam

Report S. 367. Experimental Investigation of the Post-Buckling Behaviour of Stiffened, Flat, Rectangular Plates under Combined Shear and Compression. Part III. By Ir. W. G. K. Floor. (*In English.*)

In this paper results of texts on the post-buckling behaviour of initially flat plates, published in Reports Nos. S. 300 and 328 and summarized in Report No. S. 341, were evaluated again by different methods, considered to yield more reliable results.

The original method is believed to be too conservative because of the assumptions about the friction in the joints of the loading system.

The characteristic wave form ratio P_{xy} is found to be smaller than according to refs. 1 and 2 when determined directly from the wave form measurements of the buckles in the plate after the cumbersome method described in sec. 2; it is much better in accordance with theory.

In sec. 3 the method from refs. 1 and 2 requiring the determination of the shear load carried by the plate

is again applied to calculate P_{xy}. Corrections for friction, however, are neglected, resulting in smaller P_{xy}. better in accordance with theory. A similar procedure is used in sec. 4, this time neglecting all corrections on the shear load. The resulting P_{xy} is unconservative and smaller than according to theory.

It is found in sec. 5 that the equivalent tensile stresses are increased only to a very small extent when using the method from sec. 3.

After a discussion in sec. 6 of the results obtained it is concluded in sec. 7 that the proposals for practical applications as given in Report No. S. 341 can be considered to remain valid.

SWEDEN

KUNGL TEKNISKA HÖGSKOLAN-INSTITUTIONEN FÖR FLYGTEKNIK

Stockholm 26

KTH-Aero TN 17. Effect of Geometric Dihedral of Low-Speed Static Stability Characteristics of a 40° Swept-Back Wing. By Kazimierz Orlik-Rückemann. (*In English.*)

Six component force and moment measurements at low speeds have been made to investigate the effect of geometric dihedral on the aerodynamic characteristics of a 40° swept-back wing of aspect ratio 4·5 and taper ratio 0·5. The results of the tests indicate that at small ($<10°$) angles of attack and dihedral the effective-dihedral parameter varies linearly with both geometric dihedral and lift coefficient. The variation is of such kind that an increase in the parameter caused by the increasing lift coefficient can be counteracted by increasing the negative dihedral. The lift-curve slope, $C_{L\alpha}$, at small dihedral angles ($\Gamma<10°$) varies approximately as $\cos^3 \Gamma$, if the reference area for lift coefficient is taken independent of Γ. Explanation of the variation of moment coefficients with angle of attack is given using the results of a flow investigation.

KTH-Aero TN 18. An Approximate Method for the Determination of the Increase of Maximum Lift on Thin Profiles due to Trailing Edge Flaps. By H. O. Palme and S. Stark. (*In English.*)

In the case of thin aerofoils at maximum lift it can be assumed that the forward stagnation point takes up a limiting aft position on the lower surface of the aerofoil and that this limiting position is not altered by the deflexion of a flap at the trailing edge of the aerofoil. This assumption is the basis of an approximate method for the determination of the maximum lift of thin aerofoils with trailing edge flaps. The method is derived from a knowledge of the maximum lift without a flap and from the change of no lift angle due to the flap deflexion.

U.S.A.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Secretary, N.A.C.A., Washington, D.C.

TECHNICAL MEMORANDA (TRANSLATIONS)

No. 1097. Scale Effect and Optimum Relations for Sea Surface Planing. (Report No. 439 of the Central Aero-Hydrodynamical Institute, Moscow, 1939.) By L. Sedov.

From the general dimensional and mechanical similarity it follows theory that a condition of steady motion of a given shape bottom with constant speed on the surface of water is determined by four non-dimensional parameters. By considering the various systems of independent parameters which are applied in theory and practice and in special tests, their mutual relations and their suitability as planing characterisyics are determined. In studying the scale effect on the basis of the Prandtl formula for the friction coefficient for a turbulent condition the order of magnitude of the error in applying the model data to full scale in the case of a single-step bottom is given. For a bottom of complicated shape it is shown how from the test data of the hydrodynamic characteristics for one speed with various loads, or one load with various speeds, there may be obtained by simple computation with good approximation the hydrodynamic characteristics for a different speed or for a different load. (These considerations may be of use in solving certain problems on the stability of planing.) This permits extraolpating the curve of resistance against speed for large speeds inaccessible in the tank tests or for other loads which were not tested. The data obtained by computation are in good agreement with the test results. Problems regarding the optimum trim angle or the optimum width in the case of planing of a flat plate considered from the point of view of the minimium resistance for a given load on the water and planing speed. Formulae and graphs are given for the optimum value of the planing coefficient and the corresponding values of the trim angle and width of the flat plate.

No. 1248. Investigations of Lateral Stability of a Glide Bomb using Automatic Control having no Time Lag. ('Untersuchung der Seitenstabilität einer Gleitbombe mit einer automatischen Steuerung ohne Voreilung', Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters (ZWB) Berlin-Adlerschof, Forschungsbericht Nr 1819, May 1943.) By E. W. Sponder.

The lateral stability of an automatically-controlled glide bomb as a function of the variable values of the automatic pilot and the control is investigated. In addition, with simplifying assumptions, the influence of the phugoid oscillations on the laterial stability is taken into account. A comparison of flight test results with the results of the calculation is presented.

No. 1250. Subsonic Gas Flow Past a Wing Profile. ('Obtekanie Krylovogo Profilia Pri Dokritocheskoi Skorosti Potoka'. Prikladnaya Matematika i Mekhanika. Vol. 11, No. 1, 1947, pp. 105-118.) By S. A. Christianovich and I. M. Yuriev.

A solution is presented of the problem of plane flow of a gas past a body in the presence of circulation. The solution is obtained by Chaplygin linear equations, assuming that K is constant.

No. 1259. Theoretical Investigations on the Efficiency and the Conditions for the Realization of Jet Engines. ('Recherches Théoriques sur le rendement et les conditions de réalisation des Systèmes Motopropulseurs a Réaction.' Publications Scientifiques et Techniques du Ministère de l'Air, Service des Recherches de l'Aéronautique, 1930.) By Maurice Roy.

Approximate formulae are derived for important operating parameters, and for the thrust, cycle efficiency, and over-all efficiency of several types of jet-reaction engines. The engine types considered are the dry-fuel rocket, liquid-fuel rocket, and turbine rocket, all with and without thrust augmentation. Also considered are two types of engine with rotating jets: a propeller driven by heat engine and exhaust jets, and a propeller driven exclusively by jets.

The engine types are compared with the conventional piston engine, and the flight speeds at which each engine type offers greatest promise are indicated. Areas requiring intensive research are indicated.

TECHNICAL REPORTS

Report No. 906. Determination of Stresses in Gas-Turbine Disks Subjected to Plastic Flow and Creep. By M. B. Millenson and S. S. Manson. (15 cents.)

A finite-difference method previously presented for computing elastic stresses in rotating disks is extended to include the computation of the disk stresses when plastic flow and creep are considered. A finite-difference method is employed to eliminate numerical integration and to permit non-technical personnel to make the calculations with a minimum of engineering supervision. Illustrative examples are included to facilitate explanation of the procedure by carrying out the computations on a typical gas-turbine disk through a complete running cycle.

The results of the numerical examples presented indicate that plastic flow markedly alters the elastic-stress distribution.

Report No. 907. Equations for the Design of Two-Dimensional Supersonic Nozzles. By I. Irving Pinkel. (20 cents.)

Equations are presented for obtaining the wall co-ordinates of two-dimensional supersonic nozzles. The equations are based on the application of the method of characteristics to irrotational flow of perfect gases in channels. Curves and tables are included for obtaining the parameters required by the equations for the wall co-ordinates.

A brief discussion of characteristics as applied to nozzle design is given to assist in understanding and using the nozzle-design method of this report. A sample design is shown.

Report No. 908. Stability Derivatives of Triangular Wings at Supersonic Speeds. By Herbert S. Ribner and Frank S. Malvestuto, Jr. (15 cents.)

The analysis of the stability derivatives of low-aspect-ratio triangular wings at subsonic and supersonic speeds, given in NACA TN No. 1423, is extended to apply to triangular wings having large vertex angles and travelling at supersonic speeds. The lift, rolling moment due to sideslip, and damping in roll and pitch for this more general case have been treated elsewhere on the basis of the theory of small disturbances. The surface potentials for angle of attack and rolling taken therefrom are used to obtain the several side-force and yawing-moment derivatives that depend on leading-edge suction, and a tentative value for the rolling moment due to yawing. The lift and moment due to downward acceleration are obtained on the basis of an unpublished unsteady-flow solution. All the known stability derivatives of the triangular wing at supersonic speeds, regardless of source, are summarized for convenience and presented with respect to both body axes and stability axes. The results are limited to Mach numbers for which the triangular wing is contained within the Mach cone from its vertex. The spanwise variation of Mach number in the case of yawing is neglected, although the effect must be of importance.

Report No. 909. Laminar-Boundary-Layer Oscillations and Transition on a Flat Plate. By G. B. Schubauer and H. K. Skramstad. (20 cents.)

This is an account of an investigation in which oscillations were discovered in the laminar boundary layer along a flat plate. These oscillations were found during the course of an experiment in which transition from laminar to turbulent flow was being studied on the plate as the turbulence in the wind stream was being reduced to unusually low values by means of damping screens. The first part of the paper deals with experimental methods and apparatus, measurements of turbulence and sound and studies of transition. A description is then given of the manner in which oscillations were discovered and how they were found to be related to transition, and then how controlled oscillations were produced and studied in detail. The oscillations are shown to be the velocity variations accompanying a wave motion in the boundary layer, this wave motion having all the characteristics predicted by a stability theory based on the exponential growth of small disturbances. A review of this theory is given. The work is thus experimental confirmation of a mathematical theory of stability which had been in the process of development for a period of approximately 40 years, mainly by German investigators.

GREAT BRITAIN

AERONAUTICAL RESEARCH COUNCIL

H.M. Stationery Office, London

R. & M. No. 2384. A Theoretical Investigation into the Effect of Profile Shape on the Performance of Aerofoils in Cascade. By A. D. S. Carter and Hazel P. Hughes. March, 1946. (7*s.*)

The design of axial-flow compressors and turbines is based on the two-dimensional performance of cascades of aerofoils, but very little information is available at present on the effect of profile shape on the performance of such cascades. A limited theoretical investigation has therefore been carried out in order to determine in what direction further test work on this subject could most profitably be conducted. Several conclusions, which may prove a useful guide in this connexion, are reached on the relative performance of various aerofoils. In addition a deviation rule is given for parabolic-arc cambered aerofoils, the use of which is becoming more extensive. As a guide to computors, etc., a fully worked-out example in a form suitable for routine calculation is given in an appendix.

R. & M. No. 2387. June 1945. Further Measurement of Aircraft Speed by Radar Using GL. Mk. III and SCR. 584. By G. S. Hislop, A. K. Weaver and P. H. Blundell. (4*s.* 6*d.*)

The initial attempts made in 1943 to measure aircraft speed by Radar did not yield very satisfactory results, as there were several large discrepancies between the results obtained from the Radar equipment and the pilot's observations. Consequently a further attempt using additional Radar equipment and an automatic observer in the aircraft has been carried out.

As before, the tests were made in co-operation with the Radar Research and Development Establishment (formerly A.D.R.D.E.), Great Malvern.

For these tests, two Radar equipments, an SCR. 584 which had automatic following in bearing and elevation and a GL. Mk. III, were operated simultaneously. These equipments followed a Spitfire F Mk. IX cruising under constant engine conditions at 30,000 ft., at a true air speed of about 325 m.p.h. An automatic observer was installed in the aircraft to provide a continuous record of speed and height. The technique

used and the method of computing the results were in general similar to those used in the previous series of tests.

The use of the automatic observer and of two Radar equipments made possible a much fuller analysis of the results, as the errors introduced by inaccuracies in the Radar following and by inaccuracies in flying could be distinguished and one of the uncertainties arising from the previous tests largely eliminated.

The conclusions are summarized below:

(i) Under the conditions of test and by present methods, aircraft speed can be measured by Radar to within about 5 m.p.h. The computational work involved is excessive and compares unfavourably with the accuracy so far achieved. The amount of organization required is considerable and there is at present a high proportion of unsuccessful runs. However, as more experience is gained, it should be possible to reduce the labour of computation and simplify the organization of the trials.

(ii) The agreement between Radar and aircraft results is in general better than on the previous trials. The fluctuations in Radar range, bearing and elevation have been considerably reduced by use of the SCR. 584 equipment, but are still sufficiently large to make a detailed analysis necessary before selecting the end points of any run.

(iii) The principal sources of error in speed arise from computing average speed from a pair of end points selected from a set of points containing considerable fluctuations; also from inaccuracies in the indication of aircraft course. Minor errors arise from systematic errors in the Radar, inaccuracies in the timing device and possibly from variations in wind during pairs of runs.

(iv) By taking further precautions and making the modifications in technique summarized below, it should be possible to improve the accuracy considerably. The experience of these trials suggests that Radar should give an accurate and reliable method of measuring aircraft speed, though the computational work will be considerable and the method requires somewhat elaborate preparation and organization compared with existing methods for level speed determination.

Further tests will shortly be made using a Spitfire VII flying at a high cruising speed at about 40,000 ft. Improvements in technique will include improved compass installation in the aircraft, an improved timing device for the Radar and a different method of computing the aircraft ground speed from the Radar measurements. Precautions will be taken to reduce further systematic errors in the Radar by a more rigorous lining-up process. More complete information will be provided by the use of three equipments with a photographic record at one-second intervals.

R. & M. No. 2388. June 1946. Measurement of Mechanical Actions by Electrical-Resistance Methods. By P. B. Walker. (2*s.*)

The possibilities for exploiting the principle that mechanical action may produce measurable changes in electrical resistance are reviewed in a general way, and lines of development and research are suggested. Consideration is given to extending the principle of the strain gauge to measurement of force and acceleration. The effect of fluid pressure on a resistance wire is also studied, and reasons are given why an electrical-resistance pressure gauge has prospects of being practicable and useful. The elementary elastic theory in relation to electrical resistance is given in an Appendix, together with a suggested method for calculating the change of resistance for any simple type of stress distribution.

R. & M. No. 2389. An Approximate Method for Estimating the Performance of Oxygen-Oil Rockets. By A. B. P. Beeton. June, 1946. (3*s.*)

A method is described which enables the operating conditions of an oxygen-oil rocket to be determined to a reasonably accurate degree. Less important components such as OH, O and H are not allowed for, but the method is otherwise exact and could be extended to cover these components. Curves are given for the total heat and entropy of the constituent gases, and for the relevant equilibrium constants. These values are used to derive the total heat-entropy diagrams for four mixture ratios over a range from 1 to 60 atmospheres pressure in each case. Further curves are given which show the theoretical throat and outlet areas, and also the specific impulses for expansion down to 1 atmosphere pressure.

R. & M. No. 2393. Note on Frazer's Proposed Method for the Numerical Solution of Flutter and Stability Problems. By H. L. Price. August 14, 1944. (2*s.*)

In Ref. 1, Frazer describes a simplified method for the solution of flutter and stability problems which makes possible their solution when the degree of freedom of the system is large. It is pointed out that computational difficulties arise during (*i*) the expansion of the complex determinantal equation; (*ii*) the solution of the two real simultaneous equations, therefrom derived for the purpose of obtaining the corresponding sets of values of critical speed and critical frequency. The purpose of this paper is to simplify problem (*ii*). This object is achieved by the choice of a particular 'framework' of lines, which enables the plotting of the curves to be carried out by an arithmetical process which entails the use only of factorial expressions. The construction of the double entry tables of certain standard functions of x and y is thus made unnecessary.

The T.W.A. Maintenance System

(*Concluded from p.* 24)

important phase of the work-control programme. Crew size is arrived at by analysis of the work load, with every effort made to standardize the load as much as possible so that individual speciality crews can be kept intact and work as efficient teams. This organization of crews includes foremen, inspectors and mechanics. The work-control programme has resulted in reduction of manhours and enabled the airline to establish an elapsed-time standard of 2½ days for the complete overhaul operation on a transport.

A printed inspection sheet and a series of work-control cards for each numbered checking and servicing operation to be performed at line stations on the different types of aircraft in service are issued to each crew handling the work. The crews are divided into numbered groups specializing in different classes of work, as metal, hydraulic, electrical, etc. For overhaul Operation 5 on the Constellation 049 there are, for example, twenty-five mechanic groups and eighty work-control cards.

Planning and Handling Special Work

If aircraft modifications are scheduled coincident with overhaul, the base pre-plans the work and does as much prefabrication of parts as possible and assembles them and other required units in a properly identified kit to be delivered close to the work done.

The modifications, except those made mandatory by C.A.A. directive or decided upon by company management as urgent safety measures or to effect savings that will amortize the cost over a six-month period, are generally accomplished with approval of the management. For example, the overhaul base planned and executed modifications that converted six DC-4's into 60-passenger high-density transports for entry into the sky-coach, low-fare field. Also the interiors of twelve Constellation 749's in international service were converted from a seating capacity of 43-49 to 57 passengers preparatory to placing them in domestic service when the newer 749SA's on order from the Lockheed factory were received.

Doing such work during the winter, or other low-activity months, stabilized employment and effected the changes at less cost than if made by an outside contractor.

One of the largest of the eight basic shops into which the overhaul department is divided is the engine shop, where all Constellation engines are overhauled. Complete engine run-up and testing facilities were required for the base in 1946, when T.W.A. leased the government-built experimental engine-test cells at the wartime Pratt & Whitney engine plant south of Kansas City.

Douglas DC-3 and Boeing 307 aircraft were purchased from war surplus at such advantageous prices that overhaul of the engines used in them has not been warranted. It is expected that these aircraft will be retired before overhaul of the engines becomes necessary.

Production and Inventory Control

A current project of major assistance is the introduction of a programme for control of inventory and shop production. This system supersedes the former practice of trying to forecast unit by unit the requirement for the following month as an indication to foremen of the work load to be accomplished—a system that lacked accuracy in foretelling the number of units that would be needed. The new master control plan calls for prompt overhauling of an unserviceable unit sent in by a station and its return to that station if the station is short of its allotment. It also requires advance production of needed parts and units for airframe and engine overhaul kits, and to restore depleted stock. These needs can be forecast very accurately and only enough parts are produced to meet current requirements.

The plan allows a minimum provision of parts for new aircraft types because the parts are re-used, and unless they are installed on a plane, placed in stock in a line station, or are undergoing overhaul in the shop, they are held as unserviceable and are not immediately overhauled.

A small group of work dispatchers rigidly control the number of parts throughout the entire airline system—in the shop, while being shipped, and on stock shelves. The master control office routes all movements of material. When components are dispatched to the shop for overhaul, they move on a definite schedule of work time so that none will be delayed in any part of the system. It controls all parts normally overhauled at the overhaul base and co-ordinates requirements, available inventory and shop productive capacity, thereby getting maximum utilization of inventory without over-provisioning.

Service Trouble Committee

Another recently initiated improvement of importance is a service trouble committee comprised of representatives of all stations of the engineering and maintenance department. It investigates all maintenance problems that arise concerning mechanical operation of the aircraft and initiates action to be taken to correct the trouble. Its function is to determine parts or units that need repair or re-design to eliminate mechanical malfunctioning that presents a problem in transport operation or seems likely to do so.

Work Efficiency Increased

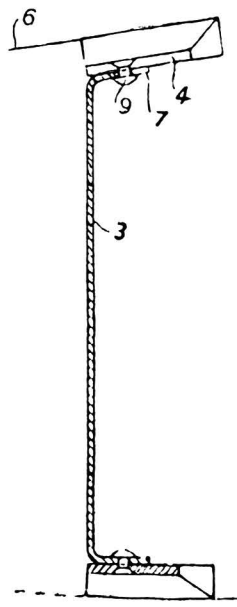
Great improvement in efficiency has resulted from the planning section's establishment of standards for accomplishment of scheduled overhaul and maintenance work. Against these standards the cost accounting department furnishes the engineernig department a report of actual cost of each operation. Two methods engineers of the section devoted some study to methods of performing Operation 10 on the DC-3, for example, and by systematic sequencing of the work and delegation of progress men to provide materials and equipment to the work area as needed, the manhours for the operation were reduced from 5,000 to 2,800—a 49 per cent improvement in efficiency.

Month in the Patent Office

These abstracts of British Patent Specifications are taken, by permission, from the officially prepared abridgments classified in Groups. Sets of Group abridgments can be obtained from the Patent Office, 25 Southampton Buildings, W.C.2, sheet by sheet as issued, at a subscription of 10s. per Group. Copies of the full specifications are obtainable at the same address, price 1s. each.

602,475. Aircraft Framework. Soc. Nationale de Constructions Aeronautiques du Nord. June 11, 1945, No. 14,797. Convention date June 13, 1941. (Class 4.) (Also in Group X.)

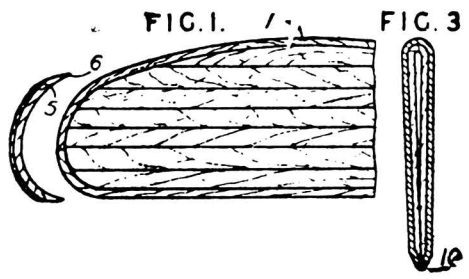
FIG. 3.



Specification No. 602,475

A beam, particularly the wing spar of an aircraft, comprises flanges 4 of rectangular section lying parallel to the covering 6 of the wing or other structure, and a web 3 whose edges 7 are bent over and secured to the flanges 4, the section of the flanges 4 varying along the beam. The flanges 4 may be formed by sawing rolled bar and may be formed with recesses or slots to receive the edges 7 of the web and the securing rivets 9.

FIG. 1. FIG. 3



602,628. Propeller blades; plane coverings. B. Jablonsky. Sept. 28, 1945, No. 25,180

The curved leading edge of a laminated air-screw blade 1 or other curved non-metallic body is reinforced by a hollowed out composite sheathing that comprises a metal sheet 5 at its convex side and one or more fibrous laminae 6 at its concave side bonded together by a thermo-setting adhesive and secured to the blade or body also by a thermo-setting adhesive. In a modification the sheathing may form a tip for the blade, being doubled upon itself, the fibrous laminae being innermost and joined at the trailing edge by a soldered seam 10, with an extension from the tip to protect the adjacent leading edge. The sheath may be applied to aerofois, rudders or the like. Specification 563,900 is referred to.

FIG. 1.

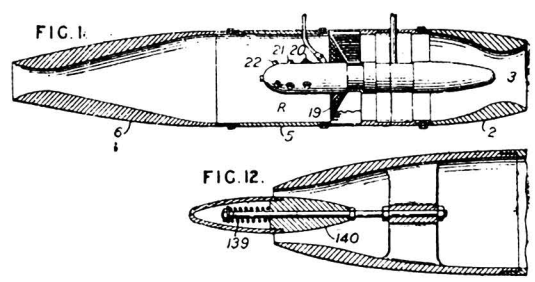


FIG. 12.

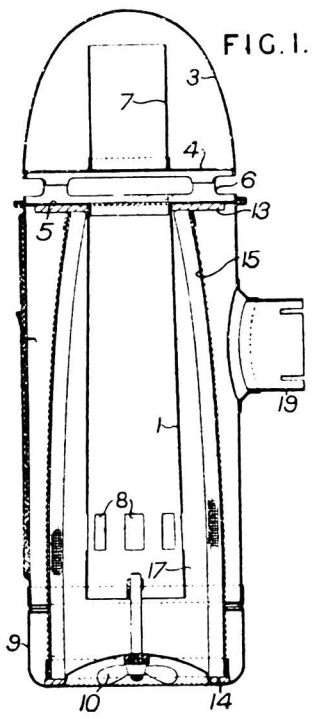
602,807. Jet propulsion. Aerojet Engineering Corporation. June 30, 1945, No. 16,706.

A jet-propulsion device comprises a cylindrical shell 5, with converging inlet and outlet sections 2, 6. Surrounding medium, e.g. water, enters at 3 passes through valve assembly 19 to reaction chamber R, where substances which react with this medium are injected through nozzles 20, &c. Pressure generated closes valves 19 and ejects medium rearwardly. Flow of reagent is controlled by a water-driven oscillatory valve. Pressure in the reaction chamber is maintained automatically by a spring-loaded tailpiece, a block 140 in the outlet nozzle controlled by spring 139, FIG. 12, or by expansion chamber on space R maintained by air pressure. Reagents such as alkaline earth metal hydrides suspended in carbon tetrachloride are used with water or Al $(BH_4)_3$.

602,855. Silencing gaseous currents. C. G. Vokes. March 13, 1946, Nos. 7,877 and 12,750.

An air intake silencer filter comprises inlets 6, a high-frequency eliminator 3, a low-frequency silencer 17, fibrous or other filtering material 15, and an outlet 19 connected to the engine intake. The high frequency eliminator is formed by a pipe 7 leading to the closed

FIG. 1.



Specification No. 602,855

chamber and arranged opposite a pipe 1 apertured at 8, the pipes being mounted on diaphragms 4, 5. The filtering material is attached to pleated gauze and is compressed to conical shape as shown. It is held against felt washers 13, 14 by a cover 9, retained by a wing-nut 10. Alternatively a brush-type filter may be used. Specification 543,055 is referred to.

602,859. Inlet and exhaust silencers. C. G. Vokes, C. M. Streete and Vokes, Ltd. April 24, 1946, No. 12,408.

FIG. 2.

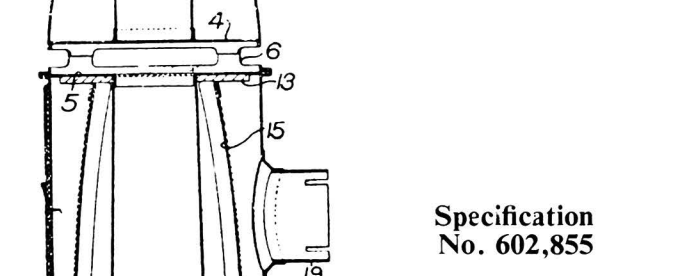
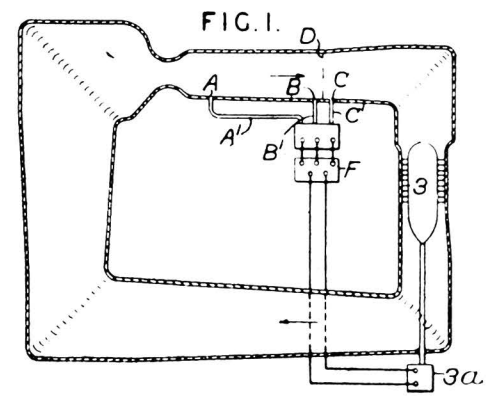


FIG. 3.

A silencer for gaseous inlet or exhaust streams flowing to or from an apparatus generating sound waves comprises an inner tube for the passage of the gases, the tube being provided with slots or apertures, spaced to register with the peaks of the sound waves or their harmonics, and giving access to resonant sound chambers arranged around the tube. In the exhaust silencer shown in FIG. 2, the gases enter at 10 into the inner tube 5 which communicates through the slots 8 with resonant chambers formed in the annular space between tubes 5 and 6 by means of the baffie 11. The tube 6 is perforated and the space between it and a third coaxial tube 7 is filled with sound absorbing material. The centres of the sets of circumferential slots register with the peaks of the waves and each set may be axially duplicated in such a way that the space between any two slots of one set will be longitudinally aligned with a slot in the next set. Duplicating is usually most necessary for the first few sets (the first three in FIG. 2) in order to deal satisfactorily with the lower harmonics. The slots are made as narrow as possible, and outwardly facing vanes are provided on the edges remote from the gas inlet to keep gas flow smooth. A silencer is described in which there are two units similar to the above, but with one slidable in the other. FIG. 3 shows an inlet silencer for a blower constructed on the same principle; the sound absorbing material is dispensed with.

FIG. 1.



Specification No. 602,155

603,155. Gaseous fluid flow systems operating under supersonic velocity conditions. Power Jets (Research and Developments), Ltd, and A. G. Smith. Feb. 1, 1945, No. 2,611.

In a gaseous fluid flow system in which, when operating at the design point, velocity conditions obtain giving rise to a shock wave, means are provided for measuring the static pressure at two spaced points in the direction of flow, one on either side of the position at which the shock wave forms, and for controlling the conditions of operation fo the system in accordance with the indication of the pressure-measuring means to maintain a low and a high pressure upstream and downstream of the points respectively. FIG. 1 shows a supersonic wind tunnel with static pressure orifices A B C of which B and C are located so as to include between them the zone in which the shock wave at the junction of the supersonic and subsonic sections form, and A is located well upstream of the zone, while FIG. 2 shows an aircraft wing with a variable-area air inlet 26 for operating under supersonic velocity conditions. The size of the air inlet is varied by pivoted flaps 27, and static pressure leads A, B, C are formed in a central casing 29. In each case under normal conditions with the shock wave D located between B and C, the points A and B are at the same pressure,

FIG. 2.

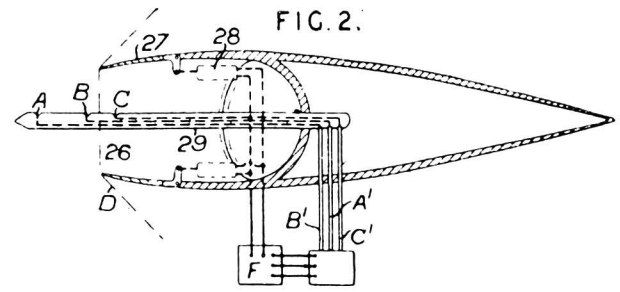
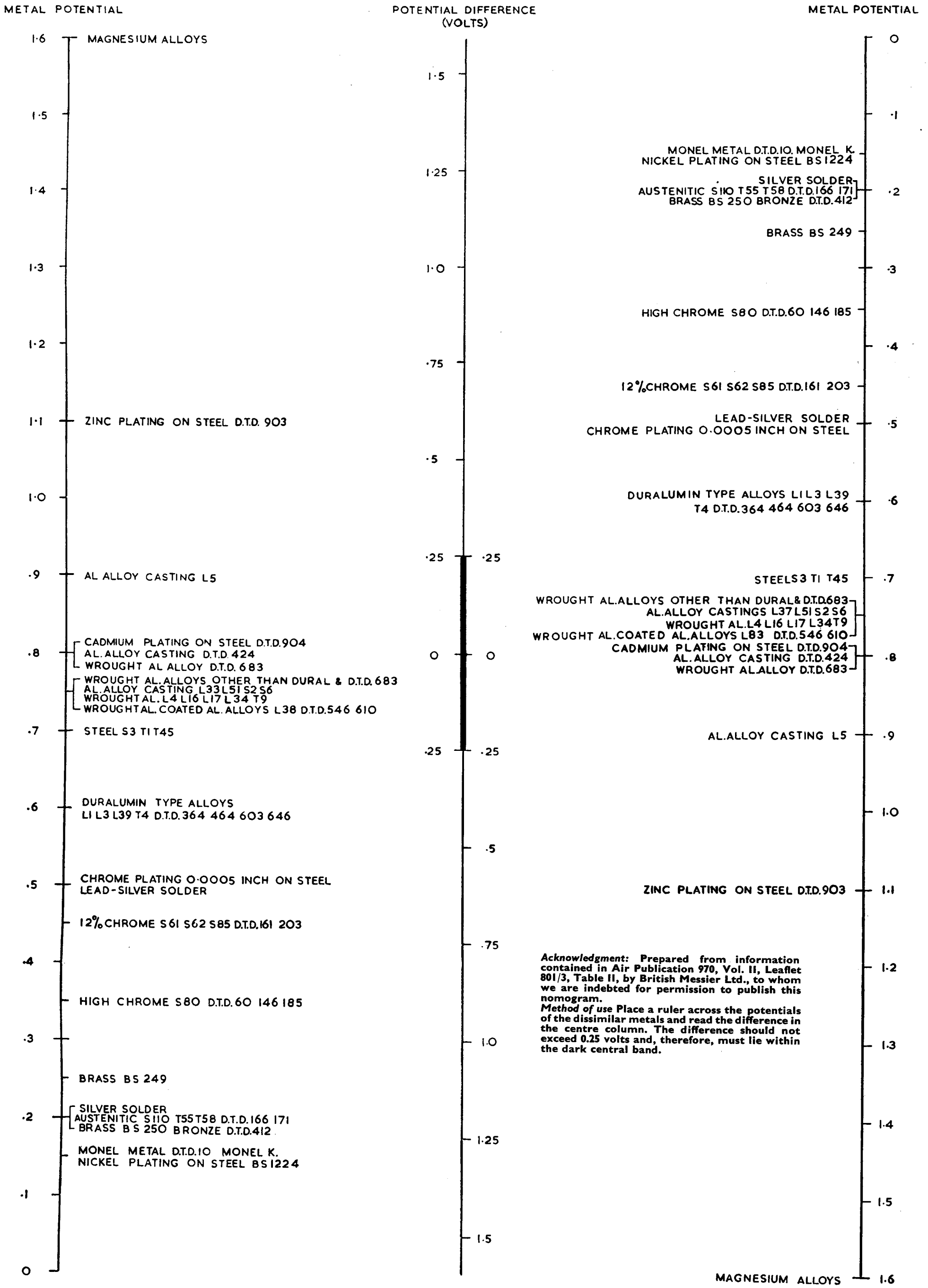


FIG. 3.

lower than that at C, but if conditions are such as to cause the shock wave to move upstream between A and B the pressure at A remains unaltered while the pressure at B rises to the value at C. The pressure orifices A, B, C may be connected to gauges, and the speed of the electric motor 3*a* or the jacks 28 controlling the flaps 27, controlled manually in accordance with the indications of the gauges. FIG. 3 shows an automatic control system in which the orifices communicate with pairs of capsules 5, 6 and 7, 8 respectively, which are interconnected by rigid links 9, 10 operating, through links 11, 12, switches 17, 22 which operate a device F for controlling the speed of the compressor motor 3*a* or the setting of the jacks 28. The circuits made by the switches 17, 22 are determined by the positions of the links 11, 12 in accordance with the pressures communicated to the capsules 5, 6, 7, 8.

(See 'A Large French General Purpose Amphibian'. AIRCRAFT ENGINEERING, July 1950, at p. 203.—EDITOR.)

A METAL POTENTIAL-DIFFERENCE NOMOGRAM

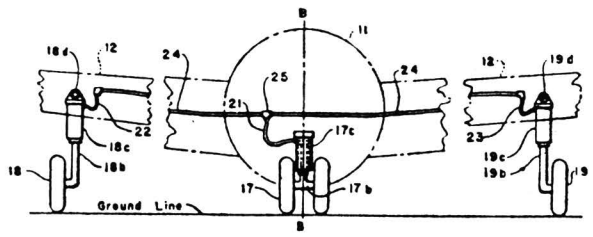


Acknowledgment: Prepared from information contained in Air Publication 970, Vol. II, Leaflet 801/3, Table II, by British Messier Ltd., to whom we are indebted for permission to publish this nomogram.

Method of use Place a ruler across the potentials of the dissimilar metals and read the difference in the centre column. The difference should not exceed 0.25 volts and, therefore, must lie within the dark central band.

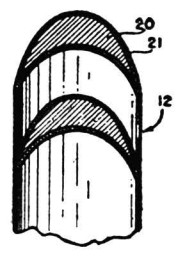
U.S. Patent Specifications

These details and drawings of patents granted in the United States are taken, by permission of the Department of Commerce, from the 'Official Gazette of the United States Patent Office'. Printed copies of the full specifications can be obtained, price 10 cents each, from the Commissioner of Patents, Washington, D.C., U.S.A. They are usually available for inspection at the British Patent Office, Southampton Buildings, Chancery Lane, London, W.C.2.



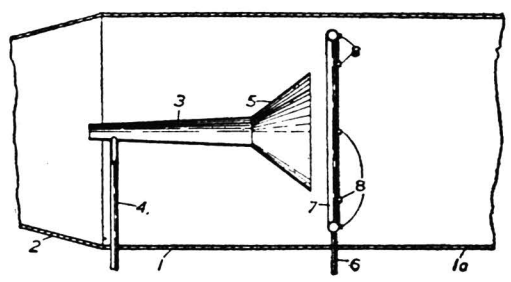
2,519,522. Aircraft Having a Plurality of Fluidly Interconnected Laterally Disposed Landing Gear Units. Edward C. Wells, Seattle, Wash., assignor to Boeing Airplane Company, a corporation of Delaware. Application January 29, 1946.

A landing gear arrangement for an aeroplane having a fuselage and a pair of laterally extending wings, a major central landing gear unit attached to the fuselage, a pair of outboard stabilizing landing gear units each attached to its respective wing and disposed laterally with respect to said central unit, each said landing gear unit including a piston-cylinder type hydraulic shock absorber, a hydraulic fluid conduit interconnecting the cylinders of each said shock absorber arranged in such manner that each of said laterally disposed units absorbs a predetermined portion of the laterally distributed load of the airplane while at rest upon the ground, cut-off valve means interposed within said fluid conduit adjacent its connection to said cylinders arranged to prevent loss of fluid from said cylinders in the event of rupture of said fluid conduit at rates of fluid flow beyond the normal equalizing flow between said shock absorber units, and a further central landing gear unit longitudinally disposed with respect to said major central unit for absorbing a portion of the longitudinally distributed load of the aeroplane while at rest upon the ground.



2,520,373. Turbine Blade and Method of Making the Same. Nathan C. Price, Los Angeles, Calif., assignor to Lockheed Aircraft Corporation, Burbank, Calif. Application January 24, 1945.

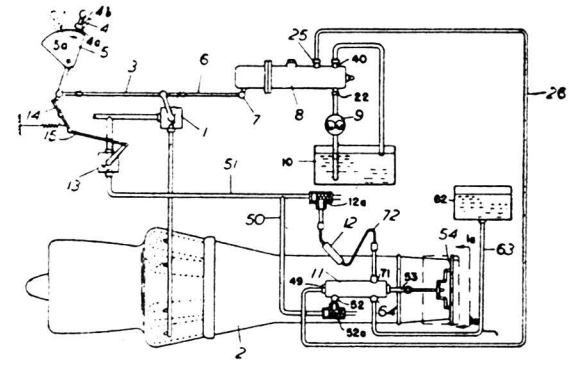
A high temperature gas turbine blade comprising a root portion for anchoring the blade and a blade portion to be acted upon by the high temperature turbine actuating gases, said portions including a common core of molded and sintered powdered tantalum, and a coating of chromium electroplated directly on the core and hot forged to size, said coating covering those surfaces of the core subject to abrasion and high temperature conditions.



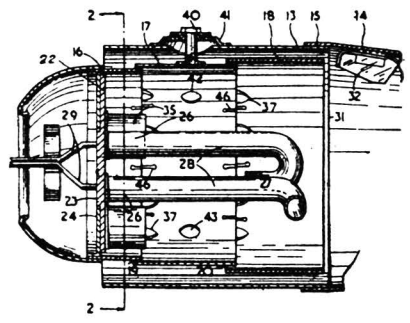
2,520,388. Apparatus for Supporting Combustion in Fast-Moving Air Streams. Allan Gilbert Earl, South Farnborough, England, assignor to Power Jets (Research and Development) Limited, London, England, a British company. Application November 19, 1947.

Combustion apparatus comprising a duct, means to supply fuel to said duct in a plurality of circumferentially spaced points in an annular path lying substantially in a single plane normal to the axis of said duct, a tube coaxially arranged in said duct, said tube having an intake end and a discharge end located adjacent said fuel supply means, said tube having conicity of increasing cross section from its intake end to its discharge end and means to admit fuel to said tube adjacent the intake end, the diameter of the discharge end of said tube being less than the diameter of the annular path of said fuel supply means.

2,520,434. Control System for Turbojet Engines with Reheat Fuel Supply System. Arthur Rynyon Devereux Robson, Peterborough, England, assignor to Power Jets (Research and Development) Limited, London, England, a British Company. Application March 18, 1947. In Great Britain March 15, 1946.



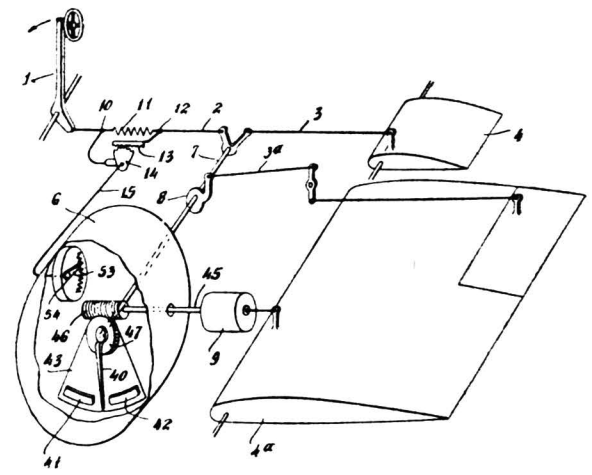
A gas turbine jet propulsion engine for aircraft comprising a turbine providing propelling power, compressor means including a compressor driven by said turbine and always operating therewith to compress air for use in the motive fluid delivered to said turbine, combustion chamber means to which the compressed air is supplied and from which motive fluid is delivered to said turbine, fuel supplying system for supplying fuel to said combustion chamber means to produce said motive fluid, jet pipe means for directing the exhaust motive fluid from said turbine away from said engine at high velocity to provide jet propulsion, variable area jet nozzle means in said jet pipe, re-heat fuel supply system and burners for supplying heat to the exhaust motive fluid in said jet pipe, an engine throttle control controlling the fuel to the combustion chamber means and control means interconnecting said throttle and said variable area jet nozzle means for operating said variable area jet nozzle means at low power throttle settings and interconnecting said throttle, variable area jet nozzle means and said reheat supply system and burners for operating said variable area jet nozzle means and controlling said re-heat burners at the highest power throttle setting.



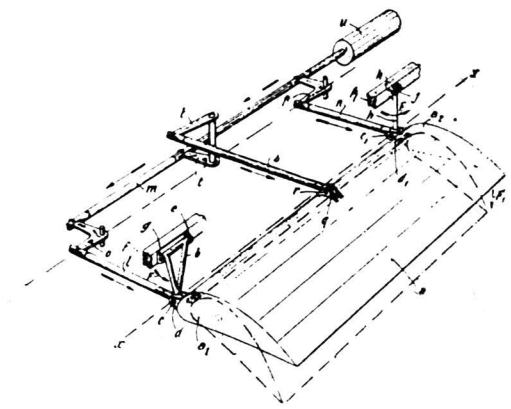
2,522,081. Combustion Chamber with Fuel Vaporizing Pipes for Internal-Combustion Turbine Plants. Sidney Allen, Coventry, England, assignor to Armstrong Siddeley Motors Limited, Coventry, England. Application August 19, 1947. In Great Britain June 23, 1947.

A combustion chamber, for an internal-combustion turbine plant, for burning a high-flash-point liquid fuel such as kerosene, including an elongated outer casing of substantially circular cross-section, a shorter elongated inner casing spaced radially therefrom, a baffle means at one end of said inner casing, a plurality of J-like pipes supported within said inner casing with the free ends of their main portions engaged with a circle of holes in said baffle means and with their curved ends outwardly of said free ends and directed towards places in said baffle means substantially midway between another circle of holes in said baffle means, slit-type nozzles in said other circle of holes respectively, and means for injecting the liquid fuel into said free ends.

2,522,284. Mechanical Device Forming a Control Assembly Applicable in Steering Elements, more particularly as used in Aircraft Production. Jacques André Marie Lecarme, Aix-en-Provence, France, assignor to Société Anonyme: Société Nationale de Constructions Aeronautiques du Sud-Est, Paris, France. Application October 30, 1946. In France January 16, 1946.



In an aircraft having a main control surface of relatively large dimensions and a laterally disposed supplemental control surface of relatively small dimensions distinct from said main surface, manual control means connected with said supplemental control surface for actuating the same, a power means connected with said manual control means and said main control surface for actuating said main surface according to the actuation of said manual means and the stress exerted thereon, and a control system interposed between said manual means and said power means and comprising a first means connected with said manual means and said power means for correspondingly determining the amplitude and the direction of their movements, a dynamometer means interposed between said manual means and said supplemental control surface responsive to the stress exerted on said manual means, and a second means connected with said dynamometer means and said power means for determining the rate of movement of said power means according to the stress exerted on said manual means.



2,524,605. Arrangement for Securing and Controlling a Movable Flap at the Trailing Edge of an Airplane Wing. Lucien Servanty, Paris, France, assignor to Société Nationale de Constructions Aéronautiques du Sud-Ouest (Société Anonyme), Paris, France, a company of France. Application May 15, 1945. In France November 23, 1944.

The combination with an aircraft wing, of a movable flap located at the trailing edge of the wing and having its forward portion normally nesting in the trailing portion of the wing, a pair of spanwise spaced links connecting the flap to the wing in suspended relation, said links at their lower ends being connected by universal joints to the flap, one of said link connections with the wing being a hinge joint the axis of which is parallel to the leading edge of the flap and the other of said link connections with the wing being a universal joint the centre of which lies in the axis of the hinge joint, both links being arranged to move wholly within the aerofoil rear tip portion of the wing, a flap turning connecting rod within the wing disposed between said links and movable in a fore and aft direction, one end of said connecting rod being connected by a universal joint to the flap at a point above and to the rear of the pivotal axis of the connexions between the links and the flap, additional connecting rods within said wing, each of said connecting rods having one end connected to one of the universal joints between one of said links and the flap and means within the wing for simultaneously moving all of the connecting rods in a direction fore and aft of the wing to move the flap in a curved path fore and aft relatively to the wing.