

The AERONAUTICAL Journal



Contents

P.R. Ashill, G.L. Riddle and M.J. Stanley Separation control on highly-swept wings with fixed or variable camber	317
G. Chiocchia and S. Pignataro On the induced drag reduction due to propeller–wing interaction	328
W.R. Quinn Turbulent mixing in a free jet issuing from a low aspect ratio contoured rectangular nozzle	337
C.P. Yeung and L.C. Squire A study of the three-dimensional interaction of wakes and boundary layers	343
Library reviews, additions and reports	352

Volume 99 Number 988

October 1995

THE AERONAUTICAL JOURNAL

Aims and scope

The aims and scope of The Aeronautical Journal are intended to reflect the objectives of the Society as expressed in the Charter of Incorporation. Briefly these are to encourage and foster the advancement of all aspects of aeronautical and space science. Thus the topics of the Journal include all those which are covered by the various Sections and Groups of the Society such as fluid mechanics and aerodynamics, propulsion, structures and materials, rotorcraft, astronautics and guided flight, dynamics and control, aeromarine technology, aviation medicine, air transport, airworthiness and maintenance, test flying, flight simulation, air law, management studies, history of aviation and manpowered aircraft. Thus papers are solicited on all aspects of research, design and development, construction and operation of aircraft and space vehicles. Papers are also welcomed which review, comprehensively, the results of recent research developments in any of the above topics.

The AERONAUTICAL Journal

Volume 99 Number 988 October 1995



Editor
B.F. Baldwin, BSc, MRAeS

Deputy Editor
S.M. Penney, BEng, Grad RAeS

Editorial Assistants
C.S.C. Male, BSc(Eng), Grad RAeS
I.R. Sheppard, BEng, Grad RAeS

RAeS Director
R.J. Kennett, FIMgt, FInstD, FCIT,
FRSA, AFAIAA, FRAeS

Published by
The Royal Aeronautical Society
4 Hamilton Place, London W1V 0BQ.
Tel: 0171-499 3515
Fax: 0171-499 6230

Advertisements
Chris Marot/Trevor Hornshaw
Marot & Co
3 Albion Buildings
1 Back Hill, London EC1R 5EN
Tel: 0171-278 3686
Fax: 0171-837 2764

Reproduction of any of the papers published in this journal is not permitted without the written consent of the Editor.

The content does not necessarily express the opinion of the Council.

Printed by
Manor Park Press,
Unit 7, Highfield Industrial Estate,
Edison Road, Hampden Park,
Eastbourne.

Subscriptions: £200 a year, post free.

RAeS members: £23 a year.

Single copies, including back numbers: £25.

Non-member subscriptions from
The Royal Aeronautical Society
Publications Subscriptions Department,
Bradley Pavilions, Bradley Stoke North,
Bristol BS12 0BQ, UK.
Tel: 01454 620070.
Fax: 01454 620080.

ISSN: 0001-9240

The Royal Aeronautical Society is a registered charity.

**PUBLISHED MONTHLY
EXCEPT JUNE AND AUGUST**

Editorial Advisory Board

Chairman: Dr E.W.E. Rogers

Aerodynamics

Professor P.W. Bearman, *Department of Aeronautics, Imperial College*

Aerospace medicine

Air Vice Marshal P. Howard, *formerly RAF Institute of Aviation Medicine*

Air traffic control and simulation

G.C. Howell, *former Civil Aviation Authority chief scientist*

Airworthiness

R. Ashford, *formerly Civil Aviation Authority and the European Joint Aviation Authorities*

Avionics and systems

Professor D. McLean, *Department of Aeronautics & Astronautics, University of Southampton*

P.A. Hearne, *formerly GEC-Marconi Avionics*

Computational fluid mechanics and propulsion

Professor P. Stow, *Rolls-Royce*

Flight testing, flight operations and air transport

Captain W.D. Lowe, *British Airways*

Maintenance and airworthiness

G.B. Ratcliffe, *RAeS Airworthiness and Maintenance Committee*

Noise, aeroelasticity and fluid mechanics

Professor E.G. Broadbent, *Department of Mathematics, Imperial College*

Rotorcraft and structural dynamics

Professor D.E.H. Balmford, *formerly of Westland Helicopters*

Space technology

R. Gibson, *Inmarsat*

Structures and materials

T. Sharples, *Military Aircraft Division, BAe Defence*

**Incorporating The Aeronautical Quarterly and the Journals of
The Institution of Aeronautical Engineers and
The Helicopter Association of Great Britain.**

DIVISIONS AND BRANCHES THE ROYAL AERONAUTICAL SOCIETY

Australia Branches at: Adelaide, Brisbane, Canberra, Melbourne and Sydney.

President: Air Cdre W.J. BELTON, CEng, FRAeS. *Hon. Secretary:* R.D. BARKLA, CEng, MRAeS. PO Box 573, Mascot, NSW 2020.

New Zealand Branches at: Auckland, Blenheim, Canterbury, Hamilton, Otago, Palmerston North and Wellington.

President: Wg Cdr R.M. ALLAN, CEng, FRAeS, RNZAF Retd. *Hon. Secretary:* J.H. MOUNCE, CEng, MRAeS. Tech Service Manager — Int'l & Dom, AKL35 Air New Zealand Limited, Private Bag, Auckland 1.

Pakistan President: Air Marshal M. AZIM DAUDPOTA, FRAeS. *Hon. Secretary:* Dr S.A. HASAN, CEng, FRAeS, 4th Floor, IEP Building, 177/2 Liaquat Barracks, Karachi 75530. Tel: 92 7780233.

Southern Africa President: Professor E.A. BUNT, CEng, FRAeS. *Hon. Secretary:* Mrs LESLIE STOKOE, PO Box 9168, 1625 Eldeen, Republic of South Africa.

Zimbabwe President: Gp Capt E. CHINGOSHO, MRAeS. *Hon. Secretary:* A.S. MATIKITI, IEng, AMRAeS. Engineering Dept., Air Zimbabwe, PO Box 1931, Harare, Zimbabwe.

Bedford

President: Air Cdre P. LIDDELL, RAF.
Chairman: G.W. WOODS, CEng, MRAeS.
Hon. Secretary: C.I.P. MARTIN, AMRAeS. Hunting Engineering, Reddings Wood, Amphil, Bedford MK45 2HD. Tel: 01525 843760.

Belfast

President: T. STONE, FRAeS.
Chairman: W.H. MORRIS, CEng, FRAeS.
Hon. Secretary: Dr S.T. McILWAIN, Grad RAeS. Aerodynamics, Mechanical Engineering Group, Short Missile Systems, Alanbrooke Road, Castlereagh, Belfast, Northern Ireland BT6 9HB. Tel: 01232 465650.

Birmingham, Wolverhampton and Cosford

President: S.L. HISCOX, MRAeS.
Chairman: R.J.P. HOWARD, AMRAeS.
Hon. Secretary: A.R. BANBURY, CEng, MRAeS, 13 Grasmere Close, Tattenhall, Wolverhampton WV6 9DP. Tel: 01902 745957.

Boscombe Down

President: Air Cdre C.J. CRUICKSHANKS, AFC*, FRAeS.
Chairman: Dr D.W. WILLIAMS, CEng, FRAeS.
Hon. Secretary: Wg Cdr P.L. WOOD, CEng, RAF Retd, MRAeS, c/o APR, DTEO Boscombe Down, Salisbury, Wilts SP4 0JF. Tel: 01980 662551.

Bristol

President: Professor J.E. TALBOT, CEng, FRAeS.
Chairman: D.C. GREENMAN, CEng, MRAeS.
Hon. Secretary: A.J. EVANS, Grad RAeS. Rolls-Royce, APSD-Mil, WH-34, PO Box 3, Filton, Bristol BS12 7QE. Tel: 0117-979 5295.

Brough

President: D. BRANNOCK.
Chairman: S.J. BLEE, CEng, MRAeS.
Hon. Secretary: N. PENISTONE. Structures Development, British Aerospace (Military Aircraft), Brough, East Yorkshire HU15 1EQ. Tel: 01482 663119.

Cambridge

President: Professor M. GASTER, FRS, CEng, FRAeS.
Chairman: Wg Cdr P.N. GILBERT, CEng, MRAeS.
Hon. Secretary: D.N. WHITEHEAD, CEng, MRAeS. Aircraft Design Office, Marshall Aerospace, The Airport, Newmarket Road, Cambridge CB5 8RX. Tel: 01223 373232.

Cardiff

President: Gp Capt I.F. EASTON, CEng, FRAeS.
Chairman: D.E. WEEDING, CEng, MRAeS.
Hon. Secretary: Eurling D.J. CARRINGTON, CEng, MRAeS. OC Eng Div Co-ord, RAF St Athan, Barry, South Glamorgan CF6 4WA. Tel 01446 798800.

Chester

President: D. WARING.
Chairman: J.R.F. YOUNG, AMRAeS.
Hon. Secretary: Dr J.E. ROBINSON. Padeswood Lodge, Padeswood, Mold, Clwyd CH7 4JF. Tel: 01244 365461.

Christchurch

President: M.J. COBHAM, CBE, FRAeS.
Chairman: K.W. NORRIS, FRAeS.
Hon. Secretary: M.G. PORTER, CEng, MRAeS. Flight Refuelling Ltd, Brook Road, Wimborne, Dorset BH21 2BJ. Tel: 01202 882121 Ex. 2654.

Coventry

President: J.B. ROBERTS CEng, FRAeS.
Chairman: Dr B.D. HOBSON, CEng, MRAeS.
Hon. Secretary: P. SMITH, 22 Appledore Drive, Allesley Green CV5 7PQ. Tel: 01203 668712.

Cranwell

President: Air Vice Marshal A.J. STABLES, CBE, RAF.
Chairman: Wg Cdr M.F.J. NETHAWAY.
Hon. Secretary: Sqn Ldr J.E. MORTON, CEng, MRAeS. DSGT, RAF College Cranwell, Sleaford, Lincs NG34 8HB. Tel: 01400 261201 Ex. 6437.

Derby

President: P.C. RUFFLES, CEng, FRAeS.
Chairman: D.C. COOK, CEng, MRAeS.
Hon. Secretary: K. COBLEY, CEng, MRAeS. Turbine Engineering, Rolls-Royce plc, PO Box 31, Derby DE24 8BJ. Tel: 01332 249507.

Gatwick

President: M.J. WILLETT, FRAeS.
Chairman: A.J. HEATH, OBE, CEng, FRAeS.
Hon. Secretary: D.L. BATES, Associate RAeS. 52 Grant Road, Addiscombe, Croydon, Surrey CR0 6PG. Tel: 0181-654 1150.

Glasgow

President: J. TAYLOR, FRAeS.
Chairman: J. ALLAN, Grad RAeS.
Hon. Secretary: G.D. CATTO, 2 Lang Avenue, Bishopston, Renfrewshire PA7 5BL. Tel 01505 862225.

Gloucester and Cheltenham

President: D.G.M. DAVIES, OBE, CEng, FRAeS.
Chairman: R.H. ASHFORTH, CEng, FRAeS.
Hon. Secretary: R.F.J. MCCARTHY, CEng, FRAeS. Dowty Aerospace Propellers, Anson Business Park, Cheltenham Road East, Gloucester GL2 9QN. Tel: 01452 711428.

Hatfield

President: F.W. VANN, CEng, FRAeS.
Chairman: F.B. OGILVIE, AMRAeS.
Hon. Secretary: D.H. TIPPER, CEng, MRAeS, 4 Bishops Rise, Hatfield, Herts AL10 9HB. Tel: 01707 271025.

Heathrow

President: Sir COLIN MARSHALL, Hon Companion RAeS.
Chairman: D. JOHNSON, FRAeS.
Hon. Secretary: R.A. KENNEDY, IEng, AMRAeS. British Airways (S.1) PO Box 10, Heathrow Airport, Hounslow, Middx TW6 2JA. Tel: 0181-562 3366.

Isle of Wight

President: R.L. WHEELER, CEng, FRAeS.
Chairman: R.C.T. HARDING, Student RAeS.
Hon. Secretary: S. ASHWORTH, 21 Union Road, Cowes, Isle of Wight PO31 7TW. Tel: 01983 283022.

Loughborough

President: Professor G.L. WILDE, OBE, CEng, FRAeS.
Chairman: R.C.T. HARDING, Student RAeS.
Hon. Secretary: Dr P.M. RENDER, CEng, MRAeS. Dept of AAETS, Loughborough University of Technology, Loughborough, Leics LE11 3TU. Tel: 01509 223415.

Luton

President: B. NEWTON, FRAeS.
Chairman: P.J. SHARP, CEng, MRAeS.
Hon. Secretary: N.G. TOOMEY, IEng, MRAeS. c/o Monarch Aircraft Engineering Ltd (Planning Dept), Luton International Airport, Luton, Beds LU2 9LX. Tel: Work—01582 398542. Home—01234 54185.

Manchester

President: Professor J.B. SCOTT-WILSON, OBE, FEng, FRAeS.
Chairman: A.A. McDICKEN, MRAeS.
Hon. Secretary: T.M. OPENSHAW, Grad RAeS. Customer Support, PS50, Avro International Aerospace, Woodford, Stockport, Cheshire SK7 1QR. Tel: 0161-957 4661.

Marham

President: Gp Capt J. BROADBENT, DSO, DFC.
Chairman: R.A. LISTER, FRAeS.
Hon. Secretary: Flt Sgt N.P. KING, AMRAeS. Mechanical Components Flight, RAF Marham, Kings Lynn, Norfolk PE33 9NP. Tel: 01760 337261 Ex. 7589.

Medway

President: P.A. HEARNE, FEng, Hon FRAeS.
Chairman: G.R. SLEIGHT, CEng, FRAeS.
Hon. Secretary: R.T. TWINE, MRAeS. c/o GEC-Marconi Avionics Ltd, Airport Works, Rochester, Kent ME1 2XX. Tel: 01634 844400 Ex. 3534.

Preston

President: Professor D. GARDNER, FEng, FRAeS.
Chairman: M. SHARLAND, FRAeS.
Hon. Secretary: M. GILCHRIST, BEng, Grad RAeS. Weapons Management (W310D), British Aerospace Defence, Warton Aerodrome, Preston, Lancs PR4 1AX. Tel: 01772 855348.

Prestwick

President: P. BERRY, MRAeS.
Chairman: J. HOPKINS, MRAeS.
Hon. Secretary: A.R. FROST, AMRAeS, 21 Fullerton Road, Prestwick, Ayrshire KA9 2BU. Tel: 01292 478204

Shannon

President: Dr A. RYAN.
Chairman: E.J. RYAN, Associate RAeS.
Hon. Secretary: N. LYNCH.

Sherborne

President: Position vacant.
Chairman: P. SAUNDERS, IEng, AMRAeS.
Hon. Secretary: J.D. SIMPSON, Student RAeS, 27 Mill Close, East Coker, Yeovil BA22 9LF. Tel: 01935 702149.

Southampton

President: Professor G.M. LILLEY, CEng, FRAeS.
Chairman: P.R. BOYLE, CEng, MRAeS.
Hon. Secretary: D.R.J. BAXTER, CEng, FRAeS. Department of Aeronautics and Astronautics, University of Southampton, Highfield, Southampton, Hants SO9 5NH. Tel: 01703 593882.

Southend

President: BARONESS PLATT of WRITTLE, CBE, FEng, Hon FRAeS.
Chairman: D. ROBERTS, Technician RAeS.
Hon. Secretary: D. ROBERTS, Technician RAeS, 39 Eastwood Old Road, Leigh-on-Sea, Essex SS9 4PD. Tel: 01268 884033.

Stevenage

President: D. FRISTON.
Chairman: M.F. RICKETT, CEng, MRAeS.
Hon. Secretary: D. MURPHY, CEng, MRAeS. MMS Space Systems, Gunnels Wood Road, Stevenage, Herts SG1 2AS. Tel: 01438 736737.

Swindon

President: Professor M.G. FARLEY, CEng, FRAeS.
Chairman: Wg Cdr K.E. ARCHER-JONES, CEng, MRAeS.
Hon. Secretary: V.A. SIMON, 20 Hawkswood, Covingham Park, Swindon, Wilts. Tel: 01793 525350.

Weybridge

President: Professor I.R. YATES, CBE, FEng, FRAeS.
Chairman: Miss J.M. GULLAND CEng, MRAeS.
Hon. Secretary: K.J. DAVIES, CEng, MRAeS, 65 Stringers Avenue, Jacobs Well, Guildford, Surrey GU4 7NN. Tel: 01483 31529.

Yeovil

President: R.I. CASE, FEng, FRAeS.
Chairman: P.N. GODDARD.
Hon. Secretary: F.N.R. BALLAM, CEng, MRAeS. Box 285, Westland Helicopters, Yeovil, Somerset BA20 2YB. Tel: 01935 703779.

OVERSEAS BRANCHES

Cyprus

President: D.M. PANTAZIS, FRAeS.
Chairman: D.M. PANTAZIS, FRAeS.
Hon. Secretary: C. PERICLOUS, MRAeS, 8 Georgiou Christodoulou Street, 2014 Nicosia, Cyprus. Tel: 357-2-310430.

Hong Kong

President: H.E. the Governor of Hong Kong.
Chairman: R. FAIRFIELD, FRAeS.
Hon. Secretary: D. MAWDSLEY, MRAeS. Flight Safety Manager, Cathay Pacific, CPA Technical Building, HK International Airport, Kowloon, Hong Kong. Tel: (852) 2747 8206.

Malaysia

Chairman: Dato R. SINGH, IEng, FRAeS.
Hon. Secretary: Lt Col A. LATIF B. TAHA, AMRAeS, MRAF. Dept of the Air Force, Ministry of Defence, Jalan Padang, Tembak, 50634 Kuala Lumpur, Malaysia. Tel: 03-2354358.

Munich

President: Professor Dipl. Ing G. MADELUNG, FEng, Hon FRAeS.
Chairman: Air Cdre T.C. DAVIES, MRAeS.
Hon. Secretary: G.G. PARKER, Student RAeS. NAMMA, Postfach 1303, 82003 Unterhaching, Germany. Tel: 89-666 80140.

Northern Germany

Chairman: Wg Cdr G.M. NISBET, CEng, MRAeS, RAF.
Hon. Secretary: Flt Lt S.R. ARMITAGE, RAF. Air Eng 1, HQ 2 Gp, JHQ Rheindahlen, BFPO 140, Germany. Tel: 2161 47 24663.

Republic of Ireland

President: R.W. O'SULLIVAN, CEng, FRAeS.
Chairman: H. REILLY, MRAeS.
Hon. Secretary: J.J. CONERNEY, Technician RAeS. Engineering Wing, Irish Air Corps, Baldonnel, Co. Dublin. Tel: 592493. Ex. 6633.

Toulouse

President: G.C. HOWELL, FRAeS.
Chairman: A.S. McCLYMONT, FRAeS.
Hon. Secretary: W.A.N. FORD, CEng, FRAeS. Chrestias, Avenue du Bouconne, 31530 Lévisgac, France. Tel: (33) 61 85 42 58.