

# The AERONAUTICAL Journal



## Contents

**P. H. Summerfield**

The 36th Roy Chadwick Lecture —  
Manufacturing Breakout 1941-1991.  
Development in aerospace  
manufacturing techniques.

**K. Knowles, D. Bray, P. J. Bailey  
and P. Curtis**  
Impinging jets in cross flow.

**B. G. Newman and M-C. Tse**

Incompressible flow past a flat plate  
aerofoil with leading edge separation  
bubble.

**Library reviews, additions and  
reports.**

Incorporating

**The Aeronautical Quarterly**

**Volume 96 Number 952 February 1992**

# 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, 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.

## **Notes on the preparation of papers**

Acceptance of a submitted paper will depend on the results of rigorous technical review by at least two referees and on the judgement of the Editors as to the importance of the paper to readers of the Journal.

Three clear copies of the manuscript, each complete with illustrations, should be submitted. Papers should be typed in double spacing and should preferably not exceed 10 000 words. Handwritten manuscripts cannot be accepted.

A list of symbols used, both in the illustrations and in the text, should be given in alphabetical order at the beginning of the paper whether or not they are standard. All unfamiliar terms must be explained.

Symbols and formulae should be typewritten if possible. The use of dots, bars, and similar characters over symbols, or the use of dots as multiplication signs and bars for brackets should be avoided. Suffixes (subscripts) and indices (superscripts) must be clearly indicated. Complicated suffixes and indices also should be avoided where possible.

References should be numbered in the text where they occur, and a complete list of references given at the end of the paper. *The Aeronautical Journal* uses the BSI Numeric System for references — e.g. author(s), title of contribution, title of periodical, year of publication, volume number, issue number, page numbers.

Illustrations should be kept to a minimum. When the paper is first submitted they can be clear prints or graphs, sketches or photographs. If the paper is accepted, authors are asked to provide the original drawings if possible, and clear, glossy, black-and-white photographs. All diagrams should be produced to the same scale.

Manuscripts should be read critically, for example by a colleague, before submission, in order to avoid small errors which might otherwise prolong the refereeing process.

## **Conditions of publication**

An author must obtain consent, where necessary, to use any material in a paper which is copyright or the property of any other persons and of his/her or their employers.

Security clearance, if appropriate, must be obtained by the author before the paper is submitted.

The copyright of papers printed in *The Aeronautical Journal* is the property of The Royal Aeronautical Society. Permission to reprint or to use any paper will not be refused unreasonably.

Following the acceptance of a submitted paper, publication of the paper will not be unreasonably delayed.

Authors are entitled to 50 complimentary reprints of their papers. Authors may order any number of additional reprints at the time of printing and quotations can be provided.

# The AERONAUTICAL Journal

Incorporating the Aeronautical Quarterly



Editor:  
J. M. Ramsden

Production Editor:  
David Moore

Published by  
The Royal Aeronautical Society,  
4 Hamilton Place, London W1V 0BQ.  
Tel: 071-499 3515  
Cables: Didaskalos, London W1  
Telex: 262826 RAESOC  
Fax: 071-499 6230

Advertisements:  
David Harrison  
The David Harrison Partnership  
1 Cotton Hill, Bromley, Kent  
BR1 5RT  
Tel: 081-698 9456  
Fax: 081-460 7908

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

None of the papers or paragraphs  
must be taken as expressing the  
opinion of the Council unless  
otherwise stated.

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

Subscriptions: £180 per annum,  
post free.

RAeS members: £20.00 per  
annum.

Single copies, including back  
numbers: £20.

Non-member subscriptions from  
The Royal Aeronautical Society  
Publications Subscriptions Depart-  
ment, PO Box 139, Tonbridge,  
Kent TN9 1EW, UK.  
Tel: 0732 770823.  
Fax: 0732 361708

ISSN: 0001-9240

**PUBLISHED MONTHLY  
EXCEPT JUNE AND  
AUGUST**

## Contents

**35**

**P. H. Summerfield**

The 36th Roy Chadwick Lecture —  
Manufacturing Breakout 1941-1991.  
Development in aerospace  
manufacturing techniques.

**47**

**K. Knowles, D. Bray, P. J. Bailey and  
P. Curtis**

Impinging jets in cross flow.

**58**

**B. G. Newman and M-C. Tse**

Incompressible flow past a flat plate  
aerofoil with leading edge separation  
bubble.

**65**

**Library reviews, additions and  
reports.**

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

**DIVISIONS AND BRANCHES OF**

# THE ROYAL AERONAUTICAL SOCIETY

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

*President:* Air Vice-Marshal R. NOBLE, 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:* I. J. DIAMOND, Associate Member. *Hon. Secretary:* J. H. MOUNCE, CEng, MRAeS, PO Box 3813, Wellington.

**Southern Africa** *President:* B. H. PRESCOTT, CEng, FRAeS. *Hon. Secretary:* N. A. H. BARRAUD, CEng, MRAeS, PO Box 630, Kelvin, 2054, Republic of South Africa.

**Zimbabwe** *President:* K. A. BOLT, IEng FRAeS. *Hon. Secretary:* H. W. SMITH, FRAeS, PO Box 1931, Harare.

**Bedford**

*President:* L. O. HUDSON, CEng, MRAeS.  
*Chairman:* A. M. McVITIE, FRAeS.  
*Hon. Secretary:* R. BAILEY, MRAeS, College of Aeronautics, Cranfield, Bedford MK43 OAL. Tel: 0234 750111. Ex. 2171.

**Belfast**

*President:* M. I. WILD, CEng, MRAeS.  
*Chairman:* D. J. GRENVILLE, AMRAeS.  
*Hon. Secretary:* R. R. PARSONS, AMRAeS, 27 Mandeville Avenue, Stratheden Heights, Newtownards BT23 3XA. Tel: 0247 818191.

**Birmingham and Wolverhampton**

*President:* C. I. HUGHES, CEng, MRAeS.  
*Chairman:* G. P. HARRIS, CEng, MRAeS.  
*Hon. Secretary:* A. R. BANNBURY, CEng, MIProdE, 13 Grasmere Close, Tettenhall, Wolverhampton WV6 9DP. Tel: 0902 745957.

**Boscombe Down**

*President:* Air Cdre D. L. BYWATER, FRAeS, RAF  
*Chairman:* Dr D. W. Williams.  
*Hon. Secretary:* Wg Cdr P. L. WOOD, CEng, MRAeS, ATG, Armament Division, A&AEE Boscombe Down, Salisbury SP4 0JF. Tel: 0980 623331. Ex. 2572.

**Bristol**

*President:* C. H. GREEN, CEng, FRAeS.  
*Chairman:* R. STEPHENSON, CEng, FRAeS.  
*Hon. Secretary:* D. C. GREENMAN, CEng, MRAeS, Technical Training Manager, British Aerospace Airbus Division, Filton House, Bristol BS99 7AR. Tel: 0272 362057. BAE Int 2057.

**Brough**

*President:* R. I. HARESCUEGH, CEng, FRAeS.  
*Chairman:* Dr J. A. H. PETRIE, MRAeS.  
*Hon. Secretary:* Mrs A. L. FERGUSON, Student RAeS, British Aerospace Defence, Brough, North Humber-side HU15 1EQ. Tel: 0482 667121. Ex. 5679.

**Cambridge**

*President:* Professor M. GASTER, FRSc, CEng, FRAeS.  
*Chairman:* K. WESTLEY, AMRAeS.  
*Hon. Secretary:* D. WHITEHEAD, CEng, MRAeS, Marshall of Cambridge (Engineering) Ltd, Airport Works, Cambridge CB5 8RX. Tel: 0223 61133. Ex. 3541.

**Cardiff**

*President:* Vacant  
*Chairman:* J. A. STEELE, IEng, AMRAeS  
*Hon. Secretary:* Wg Cdr P. RAWSON, IEng, AMRAeS Engineering Wing, RAF St Athan, Barry CF6 9WA. Tel: 0446 798798 Ex. 4053.

**Chester**

*President:* S. A. E. DYKE, MRAeS.  
*Chairman:* Dr J. E. D. CHARLES-JONES, MRAeS.  
*Hon. Secretary:* C. E. MANN, Technician RAeS, 3 Fir Tree Avenue, Westminster Park, Chester CH4 7QY. Tel: 0244 682607.

**Christchurch**

*President:* M. J. COBHAM, FRAeS.  
*Chairman:* P. E. COURSE, MRAeS.  
*Hon. Secretary:* R. W. SMILLIE, Associate RAeS, Penny & Giles Control Ltd, Somerford Road, Christchurch, Dorset BH23 3RS. Tel: 0425 278821. Ex. 210.

**Coventry**

*President:* J. B. ROBERTS, CEng, FRAeS.  
*Chairman:* Dr B. D. HOBSON, CEng, MRAeS.  
*Hon. Secretary:* R. I. RATCLIFF, IEng, Technician RAeS, 6 Erithway Rd, Green Lane, Coventry CV3 6JT. Tel: 0203 413779.

**Cranwell**

*President:* Air Vice Marshal R. M. AUSTIN, AFC, CEng, FRAeS, RAF.  
*Chairman:* Wg Cdr A. J. PARSONS, RAF.  
*Hon. Secretary:* Sqn Ldr J. E. MORTON, CEng, MRAeS, RAF College, Cranwell, Sleaford, Lincs NG34 8HB. Tel: 0400 61201. Ex. 6437.

**Derby**

*President:* J. O. KEIR, FRAeS.  
*Chairman:* D. C. COOK, CEng, MRAeS.  
*Hon. Secretary:* C. J. ROBINSON, CEng, MRAeS, c/o Compressor Technology, Rolls-Royce plc, PO Box 31, Derby DE2 8BJ. Tel: 0332 249017.

**Dublin**

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

**Watwick**

*President:* R. ASHFORD, CEng, FRAeS.  
*Chairman:* A. G. SAYCE, CEng, MRAeS.  
*Hon. Secretary:* S. A. WITTS, MRAeS, Civil Aviation Authority, Transport Aeroplane Group, Aviation House, Watwick RH6 0YR. Tel: Work — 0293 573285. Home — 0293 573285.

**Glasgow**

*President:* Dr A. W. BABISTER, CEng, MRAeS.  
*Chairman:* F. J. MULLEN.  
*Hon. Secretary:* S. J. CRUICKSHANK, Student RAeS, T/L 123 Deanston Drive, Showlands, Glasgow G41 3LJ. Tel: 03352 78668.

**Gloucester and Cheltenham**

*President:* J. R. LIGHTFOOT, CEng, FRAeS.  
*Chairman:* J. W. LINDLEY, CEng, MRAeS.  
*Hon. Secretary:* R. F. J. MCCARTHY, CEng, FRAeS, Dowty Aerospace Gloucester, Cheltenham Road, Gloucester GL2 9QH. Tel: 0452 711428.

**Halton**

*President:* Gp Capt R. BRUMPTON, MRAeS, RAF.  
*Chairman:* Wg Cdr C. G. R. GREAVES, CEng, MRAeS, RAF.  
*Secretary:* Flt Lt D. CURVEN, RAF, O/C Aerodynamics Flight, No. 1 School of Technical Training, RAF Halton, Aylesbury, Bucks HP22 5PG. Tel: 0296 623535. Ex. 5014.

**Hatfield**

*President:* C. B. G. MASEFIELD, CEng, FRAeS.  
*Chairman:* L. BALTHAZOR, CEng, FRAeS.  
*Hon. Secretary:* J. SAUNDERS, MRAeS, Research Dept., British Aerospace Regional Aircraft, Hatfield, Herts AL10 9TL. Tel: 0707 255098.

**Heathrow**

*President:* LORD KING of WARTNABY, Comp. RAeS.  
*Chairman:* G. A. TAYLOR, CEng, FRAeS.  
*Hon. Secretary:* R. KENNEDY, IEng, AMRAeS, British Airways (S.1), PO Box 10, Heathrow Airport, Hounslow, Middx TW6 2JA. Tel: 081-562 3366.

**Isle of Wight**

*President:* Vacant.  
*Chairman:* R. L. WHEELER, CEng, FRAeS.  
*Hon. Secretary:* P. J. CHIVERS, CEng, MRAeS, Westland Aerospace, Castle Street, East Cowes, Isle of Wight PO32 6RH. Tel: 0983 294101, Ex. 2016.

**Loughborough**

*President:* Professor G. L. WILDE, OBE, CEng, FRAeS.  
*Chairman:* M. F. POCOCK, Student RAeS.  
*Hon. Secretary:* Prof. S. J. STEVENS, CEng, MRAeS, Transport Technology Dept, Loughborough University of Technology, Loughborough, Leics. LE11 3TU. Tel: 0509 223404.

**Luton**

*President:* J. M. RAINBOW, CEng, FRAeS.  
*Chairman:* C. TURNER, CEng, FRAeS.  
*Hon. Secretary:* N. G. TOOMEY, IEng, MRAeS, c/o Monarch Aircraft Engineering Ltd (Planning Dept.), Luton International Airport, Luton, Beds LU2 9LX. Tel: Work — 0582 398542. Home — 0234 54185.

**Manchester**

*President:* Professor J. L. LIVESEY, CEng, MIMechE.  
*Chairman:* M. J. TAYLOR, CEng, FRAeS.  
*Hon. Secretary:* J. C. DEAN, MRAeS, British Aerospace Regional Aircraft, Woodford, Cheshire SK7 1QR. Tel: 061 439 5050. Ex. 3951.

**Marham**

*President:* Gp Capt. G. E. STIRRUP.  
*Chairman:* Wg Cdr D. N. WILLIAMS, CEng, MRAeS.  
*Hon. Secretary:* Flt Sgt M. P. KING, AMRAeS, 617 Squadron, RAF Marham, Kings Lynn, Norfolk PE33 9NP. Tel: 0760 337261 Ex. 4423.

**Medway**

*President:* P. A. HEARNE, Hon. FRAeS.  
*Chairman:* G. R. SLEIGHT, CEng, MRAeS.  
*Hon. Secretary:* R. T. TWINE, MRAeS, c/o GEC Avionics Ltd, Airport Works, Rochester, Kent ME1 2XX. Tel: 0634 844400 Ex. 3534.

**Middle Wallop**

*President:* G. M. MCCOOMB, OBE, CEng, FRAeS.  
*Chairman:* D. J. WILLIAMS, Technician RAeS.  
*Secretary:* Staff Sgt M. A. PARKER, Validation Section, School of Aeronautical Engineering, Army Air Corps Centre, Middle Wallop, Stockbridge, Hampshire, SO20 8DY. Tel: 0264 384264

**Preston**

*President:* D. GARDNER, CEng, FRAeS.  
*Chairman:* M. MANSELL, FRAeS.  
*Hon. Secretary:* C. N. BENT, AMRAeS, British Aerospace, Defence, Warton Aerodrome, Preston, Lancs PR4 1AX. Tel: 0772 852284.

**Prestwick**

*President:* Dr W. G. WATSON, FRAeS.  
*Chairman:* D. R. SHEPHERD, CEng, MRAeS.  
*Hon. Secretary:* A. R. FROST, AMRAeS, 21 Fullerton Road, Prestwick KA9 2BU. Tel: 0292 78204.

**Sherborne**

*President:* Air Marshal Sir E. DUNN, KBE, CEng, FRAeS.  
*Chairman:* C. A. FRY, FRAeS.  
*Hon. Secretary:* G. R. RUSSELL, Grad RAeS, 18 Berkely Court, Hermes Place, Ilchester, Somerset BA22 8JU. Tel: 0935 704231.

**Southampton**

*President:* Professor G. M. LILLEY, CEng, FRAeS.  
*Chairman:* M. DRASDO, MRAeS.  
*Hon. Secretary:* D. R. J. BAXTER, CEng, MRAeS, Dept of Aeronautics and Astronautics, The University, Southampton, Hants SO9 5NH. Tel: 0703 592326.

**Southend**

*President:* BARONESS PLATT of WRITTLE, CBE, FEng, FRAeS.  
*Chairman:* M. NICOLINI, MRAeS.  
*Hon. Secretary:* G. GILLIGAN, Associate RAeS, 21 Sandleigh Road, Leigh-on-Sea, Essex SS9 1JT. Tel: 0268 883102.

**Stevenage**

*President:* J. A. HOLT, FEng, FRAeS.  
*Chairman:* Dr J. M. YOUNG, MRAeS.  
*Hon. Secretary:* A. C. K. CRESSWELL, CEng, MRAeS, PB067 British Aerospace Defence, Six Hills Way, Stevenage, Herts SG1 2DA. Tel: 0438 752027.

**Swindon**

*President:* Professor M. G. FARLEY, CEng, FRAeS.  
*Chairman:* Wing Cdr A. R. HILL.  
*Hon. Secretary:* V. A. SIMON, 20 Hawkswood, Covingham Park, Swindon, Wilts. Tel: 0793 525350.

**Weybridge**

*President:* I. R. YATES, CBE, FEng, FRAeS.  
*Chairman:* Miss J. M. GULLAND, CEng, MRAeS.  
*Hon. Secretary:* K. J. DAVIES, CEng, MRAeS, Aerodynamics Department, British Aerospace, Defence, Richmond Road, Kingston-upon-Thames KT2 5OS. Tel: 081-546 7741. Ex. 2895.

**Yeovil**

*President:* V. A. B. ROGERS, CBE, FEng, FRAeS.  
*Chairman:* R. I. CASE, CEng, FRAeS.  
*Hon. Secretary:* F. N. R. BALLAM, CEng, MRAeS, Box 269, Westland Helicopters, Yeovil, Somerset BA20 2YB. Tel: 0935 703779.

**OVERSEAS BRANCHES**

**Cyprus**

*Chairman:* Air Vice-Marshal G. A. WHITE, CB, AFC, FRAeS.  
*Hon. Secretary:* C. PERICLEOUS, MRAeS, 8 Georgiou Christodoulou, Acropolis, Nicosia, Cyprus.

**Hong Kong**

*Chairman:* S. M. JOHN, FRAeS.  
*Hon. Secretary:* M. J. POMFRET, MRAeS, MME Dept, HK Polytechnic, Kowloon, Hong Kong. Tel: Office: 3-638344. Ex. 765. Home: 3-7213732.

**Malaysia**

*Chairman:* Brig. Gen. Dato' M. MUSLIM AYOB, RMAF, CEng, FRAeS.  
*Hon. Secretary:* Major LATIF, MRAF, Dept of the Air Force, Ministry of Defence, Jalan Padang Tembak, 50634 Kuala Lumpur, Malaysia. Tel: 03-2354010.

**Munich**

*Chairman:* J. D. EAGLES, FRAeS.  
*Hon. Secretary:* D. CHINN, Student RAeS, c/o NEFMA, Arabellastrasse 16, 8000 Munich 81, Germany. Tel: 89-92803597.

**Pakistan**

*Chairman:* S. AJAZ ALI, CEng, FRAeS.  
*Hon. Secretary:* Dr. S. A. HASAN, CEng, MRAeS, 4th Floor, IEP Building, 177/2 Liaquat Barracks, Karachi 75530, Pakistan. Tel: 92-7780233.

**Toulouse**

*Chairman:* S. G. CORPUS, FRAeS.  
*Hon. Secretary:* W. A. N. FORD, CEng, FRAeS, Chrestias, Avenue du Bouconne, Levignac 31530, France. Tel: Work — (33) 6193 3560. Home — (33) 61 85 4258.