ROYAL AIR FORCE

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ROYAL AIR FORCE HISTORICAL SOCIETY

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SELECTED ABBREVIATIONS

ACHGD	Aircrafthand, General Duties
AE	Air Evacuation
AEA	Aircrew Equipment Assembly
AERDC	Aircrew Equipment Research and Development Committee
AMTC	Aviation Medicine Training Centre
ARVN	Army of the Republic of Vietnam
ASCC	Air Standards Co-ordinating Committee
CAA	Civil Aviation Authority
CAEC	Casualty Air Evacuation Centre
CBRN	Chemical, Biological and Radioactive Nuclear particles/agents
CDE	Chemical Defence Establishment (Porton Down)
FPMO	Flying Personnel Medical Officer
FPRC	Flying Personnel Research Committee
G-LOC	G-induced Loss Of Consciousness
GOC	General Officer Commanding
Gz	There is a requirement, in the context of aviation medicine, to consider acceleration (G) as vectors with respect to the human body. Conventionally, Gz denotes acceleration with reference to the long axis of the body (Gx and Gy are front-to-back and side-to-side respectively).
ICAO	International Civil Aviation Organisation
JRNMS	Journal of the Royal Naval Medical Service
LABS	Low Altitude Bombing System (as used for ‘toss’ bombing)
MOD	Ministry of Defence
MO(P)	Medical Officer Pilot
MRCA	Multi-Role Combat Aircraft (later Tornado)
MSOC	Molecular Sieve Oxygen Concentrator
NBC	Nuclear, Biological and Chemical
NVGs	Night Vision Goggles
OBOGS	On Board Oxygen Generating System
OR	Operational Requirements (Air Ministry Directorate of)
PBG	Pressure Breathing with G
PMO	Principal Medical Officer
PRU	Photographic Reconnaissance Unit
RMO	Regimental Medical Officer
RP	Rocket Projectile
SAM	(USAF) School of Aviation Medicine
TWU	Tactical Weapons Unit

AVIATION MEDICINE

RAF MUSEUM, HENDON, 24 OCTOBER 2007.

WELCOME ADDRESS BY THE SOCIETY'S CHAIRMAN

Air Vice-Marshal Nigel Baldwin CB CBE FRAeS

Ladies and gentlemen – good morning. It is a pleasure to welcome you all here on behalf of the Society and especially to see new faces – many of the medical persuasion – some of them old enough to be my own doctor…..

My usual thanks, of course, to Dr Michael Fopp and his colleagues here at the RAF Museum. As usual with our spring and autumn seminars, without their help and generosity we would be very hard pressed to do what we do as a Society.

Today's subject is the brainchild of one of our few Royal Navy members – namely Surgeon Commander Herbert Ellis. More from him later this afternoon.

Our Chairman for the day is Air Vice-Marshal Alan Johnson – himself an aviation doctor of some distinction. Soon after joining the RAF as a doctor, he qualified as a parachutist serving with a Parachute Rescue Team in Cyprus and becoming a founder member of the RAF Sports Parachute Association. Later he was a member of the Joint Services High Altitude Parachute Trials Team and, in the 1970s, led the British team at the World Parachuting Championships in Yugoslavia, the USA, and in Hungary. He finished his RAF career as Principal Medical Officer at HQ Strike Command.

Particularly relevant for today's studies, he obtained the first Diploma in Aviation Medicine, and was Head of Training at the Institute of Aviation Medicine. So, we will be in excellent and highly qualified hands.

Alan – over to you to guide us through the day.

OPENING ADDRESS

Air Vice-Marshal Alan Johnson
MB ChB FFOM MFCM DavMed FRAeS RAF (Retd)

Ladies and Gentlemen Good morning.

It gives me great pleasure to act as your Chairman today. Aviation Medicine is a branch of Occupational Medicine, a specialised branch dealing with the hazards of flight in as much as they effect those who fly, be they aircrew or passengers. Today we will be focusing primarily on military aviation medicine and the contribution doctors, both civilian and uniformed, have made to overall flight safety in the Royal Air Force but, of course, the carryover to civil flying has been considerable.

To many aviators doctors are viewed with a degree of suspicion; we are seen as characters who threaten careers or impose frustrating limitations on performance. In truth our aim has been, and will always be, to follow the principle exemplified by the motto of the RAF Institute of Aviation Medicine – '*Ut secure volent*' – 'That they may fly safely'.

Today, we are fortunate to have speakers who are distinguished in this specialised field who will recount the development of aviation medicine in the Royal Air Force, the pioneers who sought answers to the physical problems posed by the ever-increasing demands of aircraft with greater and greater performance, often at considerable personal risk.

Clinical Medicine is often referred to as the 'Quiet Art'. The story of aviation medicine in the Royal Air Force has been seldom told. Today we will try to correct that. Obviously, in the time available, it is not possible to cover all aspects but I am sure that you will find the presentations informative and interesting.

THE GENESIS OF MEDICAL SELECTION TESTS FOR AIRCREW IN THE UNITED KINGDOM

by Air Cdre T M Gibson

After initial experience as a Medical Officer at Laarbruch and on exchange with the USAF, Mike Gibson's subsequent career included medical policy and plans posts at the MOD and at the Permanent Joint HQ, command of Headley Court and a total of ten years with the Institute of Aviation Medicine. He is a prolific author of papers on aviation physiology, aviation medicine, medical law and ethics as well as on operational matters.

The Royal Flying Corps (RFC) was established in 1912 with both Army and Naval wings, which quickly grew apart until the Royal Naval Air Service (RNAS) was set up in 1914. Staff Surgeon H V Wells was appointed to the Naval Wing at the Central Flying School set up at Upavon whilst his Army opposite number was Capt E G R Lithgow RAMC. These were the first two medical officers to be awarded their wings. Yet their time at Upavon did not appear to result in any significant changes to medical policy, equipment or selection. Lithgow made arrangements for first aid cover by station medical staff for flying accidents. Wells wrote two papers published in the new *Journal of the Royal Naval Medical Service* in 1915[1] and 1916[2] in which he outlined the effects of flying, described causes of crashes and made some observations on selection. But again, the proposals made no impact on the medical profession or the military. No substantive changes in policy or procedures appeared to have followed.

From the earliest days of powered flight, there appeared to be a limited understanding of the physiological effects of flying despite the experience gained over the preceding 125 years by balloonists. Some accounts in the literature of the effects of flying displayed imagination rather than observation. Wilbur reported haemorrhaging from lips and fingernails as well as loosening of the femur in its socket.[3] Although Alder duplicated the observations of haemorrhage in 1914, he also suggested that the specific problems of flight should require specific medical tests for the selection of pilots.[4] This suggestion was repeated by Wells the following year.[5]

Part of the concerns related to accidents, of which there were many, not all deadly. Aircraft were becoming capable of greater speed and altitude and the numbers of aircraft, and thus pilots, was also growing. Dépagniat wrote that in 1909, there was one fatality for every 15,000 km flown.[6] By 1912, the safety and reliability of aircraft had developed to the extent that the mileage flown for each fatality had risen almost 100-fold. Colonel Holden in 1914, speaking at a meeting later reported in the *Aeronautical Journal*, mentioned one accident where he said the pilot was not fit to fly.[7] In the ensuing discussion, Staff Surgeon Hardey Vesey Wells, who was at that time medical officer to the Royal Naval flying school at Eastchurch, confirmed that more than one accident was attributable to physical failure of the pilot. As late as 1918, Sir William Watson-Cheyne wrote that two out of every five crashes were attributable to various forms of 'air illness'.[8] There was also evidence that medical unfitness was contributing significantly to fatalities and it was claimed that at any given flying school some 50% of pupils were non-effective and that a large number of those were not flying because of the insufficient experience and knowledge of the medical officers.[9] In the United States Army, it was reported that wastage of men and aircraft 'are too often a measure of failure, not of the aviator, but of those responsible for his fitness at the time of his crash.'[10]

The setting of standards for particular occupations is not new. For example, a law was enacted in 1788 which was intended to 'alleviate the misery' of young chimney sweeps who were not to be employed younger than the age of 6 years and who were not permitted to 'call of the streets before seven of the clock'.[11] The recognition that specific occupations faced particular hazards or gave rise to particular diseases is even older. The first monograph on diseases of an occupational group was on goldsmiths and metal workers by Ellenbog in the 15th Century[12] and this was followed by one on miners by von Hohenheim (better known as Paracelsus) written in the 15th Century but not published until after his death.[13] The acknowledged 'father' of occupational medicine was Bernadino Ramazzini who is recorded as advising physicians visiting a patient to add one question to those traditionally posed by Hippocrates, ‘What is your occupation?’[14]

Early selection for pilot duties was based on personality and class. In the very beginning, you could join only if you had your pilot’s certificate, and this limited membership to the wealthy. Later, flying training schools were set up – the first being at Upavon and Eastchurch. However, reflecting the then perceived role of the flying arms as being solely reconnaissance, the selection criteria appeared to be the applicant’s seat on a horse and eye for the country. This view was still held by some diehards as late as 1930.[15] Consequently, if you were fit enough to be in the cavalry, you were automatically fit enough to be a pilot.

When the RFC deployed to France at the start of the First World War, Major Lithgow was attached to the headquarters.[16] By the middle of the war, the RFC was organised on a brigade basis with each brigade having between five and ten squadrons, with each squadron having fifteen or sixteen flying officers, three or four ground officers and a proportionate number of men. Each squadron had a medical orderly who was instructed in First Aid by the Medical Officer. The RNAS squadrons brigaded with the RFC each had a naval medical orderly but received RAMC attendance as if they were RFC units. However, each RNAS wing (a unit of two-to-four squadrons) had its own RN medical officer. In the case of an accident, the orderly from each unit transported the casualty to the nearest hospital. Unfortunately, according to Heald, Lithgow did not appear to make any attempt to ensure that each brigade had its allocated RAMC officer.[17] However, it is more likely that his requirements were allocated a low priority, given the serious shortages of doctors experienced by the RAMC in the early years of the war.[18] The brigadier commanding the 2nd Brigade therefore acted independently to obtain one – Captain Brehmer Heald – and it was not until Major Birley arrived at the RFC Headquarters to replace Lithgow in 1917 that each brigade obtained its complement of a medical officer.

Heald had originally been on the Medical Board of the Department of Education but had joined the Royal Navy at the start of the war and was appointed to be a medical officer on board the battleship HMS *Conqueror*.[19] However, he had responded to an appeal by the Army for medical officers to transfer to assist in the training of field ambulance units and he then managed to be attached to the RFC.

Heald made his HQ No 20 Sqn, then equipped with FE2bs at Clairmarais some 8 miles from St-Omer and set about qualifying for his wings.

Shortly after this a new officer joined the squadron.[20] He was a quiet and delightful man who had just been elected to the Fellowship of his college. A week or so later, he was under arrest for cowardice. On each of three occasions when his flight had been on reconnaissance patrol, he had joined the flight above the airfield, had begun to move off with them and then broke off and returned alone. He did not know why he had done this and did not even realise that he had until after he had landed. Heald examined him and found a chronic suppurating otitis media and a history of his having been awarded his wings without ever exceeding 1,000 feet. As he had to rendezvous at about 2,500 feet for his sorties he had obviously become dizzy and disorientated. Heald made a full report in writing and in person to the brigadier and the court martial was cancelled. The officer returned to his regiment with his honour unsullied.

This experience stimulated Heald to look for other pilots who were unfit. He made a careful examination of every pilot and observer in the 2nd Brigade and found several who needed to be grounded. He then made further reports to the GOC RFC in the Field, Maj-Gen Trenchard, suggesting that potential pilots should be medically vetted before training. At this time, RFC direct entrants had to undergo the standard Army medical examination which was brief, and tailored specifically at confirming a general absence of disease, especially tuberculosis. Applicants for transfer from their regiments for pilot training were given a medical inspection by their own RMO. There were some cases where the RMO had advised that, as they were not fit for the trenches, they should be transferred to the Flying Corps. There was a very high demand for pilots because of the desperately high casualty rate then being experienced by the RFC. In the last half of 1916, Trenchard had lost almost 1,000 pilots, killed, captured, wounded or suffering from a permanent disability. In April 1917 alone, the RFC lost 316 aircrew dead or missing and the average life expectancy of a pilot arriving on an operational squadron had fallen to 17 days.[21]

Heald's report eventually reached the desk of Sir David Henderson, the Director General of Military Aeronautics (DGMA) in

London, who responded by proposing that a Special RFC Medical Board should be set up to advise on fitness for flight. The Army Medical Services, under Lt Gen Sir Alfred Keogh, agreed to the idea of the Board with the proviso that the officer in charge should be Lithgow, as he was a career RAMC officer. Heald, who had by this time crashed and broken his neck, was posted to be the other medical member as a result of a direct request by Henderson. Boarded 'fit for light duties' he arrived to take up his appointment late in 1916 a few days after Lithgow.

The Board was collocated with the HQ Army Medical Services in the aptly named Adastral House, formerly de Keyser's Hotel, on the Embankment. Initially they had only a small room on the ground floor with a table in the corner for a corporal clerk. There was no equipment, no examination room, no waiting room. Those waiting to be seen were seated in a dark corridor outside the Board's room. Within a week or two, a sympathetic staff officer in DGMA's department, Major Sir Douglas Powell Bt of the Welsh Fusiliers (who was the eldest son of a past president of the Royal College of Physicians) found them better accommodation on the third floor of the Hotel Cecil in the Strand.

Initially the workload was very high and not helped by Lithgow keeping rigidly to office hours, retiring to his club promptly after work even though there were still pilots waiting in the corridor. Although this infuriated Heald, who felt that leaving patients unseen was poor practice, he realised in retrospect that Lithgow was ill, from a condition that would kill him before the end of the war. Lithgow was also disliked in other quarters, Birley regarding him as 'merely a harmless lunatic….[who] has no mind of his own and absolutely no knowledge'.[22] However, he was amenable to Heald's request for more assistance and in due course, reinforcements arrived. Lithgow, Heald and the clerk were soon joined by additional medical staff: an excellent physician, George Sutherland; an ENT specialist, Mr Arthur H Cheatle (inventor of the Cheatle forceps); and an eminent ophthalmic surgeon, Mr Frederick Edridge-Green who was an authority on colour vision who had developed a lamp to screen for colour blindness and a test based on coloured beads.

The Board were able to reduce their workload by introducing a filter system to their examination. It was obvious to them that would-be pilots and observers needed to have good eyesight and that these tests needed to be carried out accurately and efficiently. They chose as the standard for distance vision and colour vision the eyesight tests applied to the train drivers of the Great Western Railway. The distance vision standard proposed was 6/6 in the better eye and no worse than 6/12[23] in the worse eye provided the candidate could reach 6/6 with both eyes together.[24] This compared to the existing standard of no worse than 6/12 in each eye unaided, provided 6/9 in the worse eye and 6/6 in the better could be reached with glasses. The proposals caused some consternation, the consultant ophthalmologist to the Army in the Field writing that 'adoption of the new standard in full would be keenly resisted'.[25] However, the new standards were applied to all new candidates.

Dr E C Clements, who was a part-time civilian doctor attached to an air station near his primary practice in Lincoln, argued that there should be additional testing for dysphoria. This was a condition where a latent squint lead to a difficulty in obtaining fused, binocular vision. Clements believed that this condition had led many individuals to misjudge their landings – either by flying into the ground, or by rounding out whilst still 10 feet up – and then crashing. Described by a colleague as 'lazy, kind, walrus-moustached'[26], he was co-opted to the team and introduced eye muscle exercises to minimise the problem. By this means, he was able to return many unsuccessful candidates to the training machine.[27]

Anyone failing the eye tests was rejected immediately. Successful candidates then went to the ENT surgeon because of Heald's experiences in Flanders and because of the view that good hearing and balance were also essential. Cheatle devised two tests – one where the candidate had to balance on one leg with his eyes closed, and one where he had to raise a tuning fork balanced on a cigar box lid from a desk to shoulder level and back. Once over these two hurdles, the candidate then had a detailed medical history taken before undergoing a thorough physical and rudimentary psychological examination.[28] Finally, they went before the two commissioned members of the Board for a final decision.

The Board started by examining pilots who were due to return to flying duties after illness or injury. On an almost daily basis they came across some who should have never been passed fit for flying in the first place. One example was a pilot with an obvious history of epilepsy. It soon became apparent that they were only seeing a very small proportion of applicants for flying duties and not all of those wanting to return to the Front after injury or illness.

At that time, the attitude of the Army Medical Services was, 'What evidence do you have that any of your new, quaint methods are choosing any better pilots than the ordinary recruiting Boards?' The team took up the challenge and produced from the training squadrons lists of those candidates who had been through the ordinary system and those who had been through the Special RFC Medical Board. The result showed that the cost of expanding the Board to deal with everyone would be more than offset by the saving from failure of medically unfit pupils. The first big expansion of the medical board took place in the summer and autumn of 1917. Two large, adjoining houses in Arkwright Rd, Hampstead, were requisitioned and the staff increased.

It was as a result of his attendance at various meetings concerning a medical service for the proposed Royal Air Force that Heald became acquainted with Sir Walter Fletcher, the secretary of the Medical Research Committee (MRC – it did not become the Medical Research Council until 1919). One of the meetings decided that high priorities should be afforded to the investigation of a scientific basis for special tests for aircrew and the problems experienced by aircrew at high altitudes. It was to Fletcher that Heald turned for advice. Fletcher immediately thought of, and offered the services of, Dr Martin Flack[29], an offer Henderson accepted 'with cordial appreciation'.[30] Flack was already a distinguished physiologist, having discovered the sino-atrial node of the heart when working with Sir Arthur Keith. He was employed as a physiologist by the MRC but had been given an honorary commission as a captain in the RAMC to carry out pathological work for HQ London District. Flack was later remembered by one Director General of the Medical Service (DGMS) as 'stoutish, with no military bearing whatsoever'[31] and by an earlier DGMS as 'generous, gesticulating, tubby, vain, warm-hearted….always getting brainwaves – not always good but sometimes very good'.[32]

The MRC also offered its facilities at Mount Vernon Hospital and provided some clerical support and the use of some apparatus.

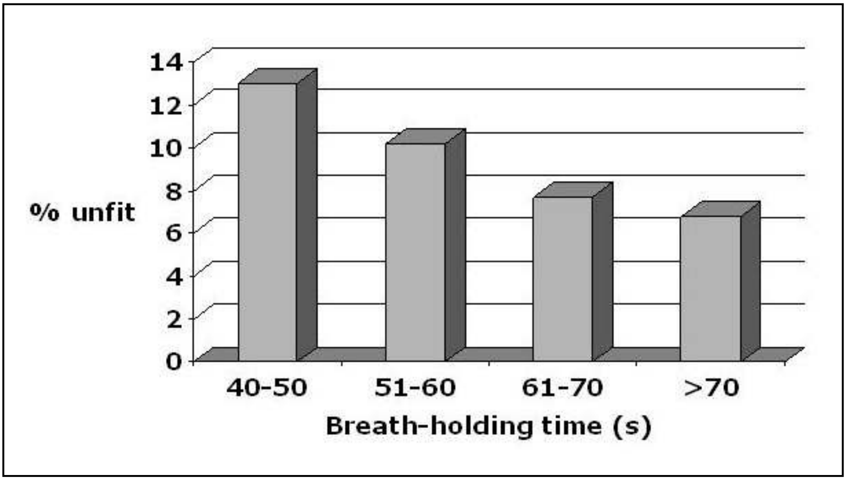


Figure 1. Failure rate in the first year of flying training related to breath-holding capacity. After Flack (1920).

Overall, the intention was to identify those who might suffer in flight from headache, dizziness, fainting or other symptoms associated with lack of oxygen. Within two weeks, Flack had proposed some additional tests and the Board set about validating them. Flack compared the respiratory responses of fit pilots with those grounded because of the stress of flying and devised four tests. These were the measurement of respiratory capacity, breath-holding capacity, maximum expiratory force and the sustaining of a 40mm column of mercury with the breath held for as long as possible. The last test was applied with the pulse being taken to provide an indication of cardiovascular stability. Flack proposed to the Board that all candidates should have a vital capacity greater than 3 litres. In addition, all those selected for high flying should have a vital capacity greater than 3.4 litres and be able to hold their breath for more than 45 seconds. Flack also used the tests to identify those suffering from flying stress. An example of the results achieved by study of just one of the Flack tests is at Figure 1.[33]

Much of the research work carried out with, and on behalf of, the air services during the war was brought together and published by the MRC in 1920.[34] At the same time, a textbook of aviation medicine was published, written by Surgeon Lieutenant Henry Graeme

Anderson[35], with a chapter on applied physiology contributed by Flack. The Flack tests were used for the next 20 years and in some air forces for much longer than that – until the reliability of administration of oxygen in flight improved enough that a tolerance to hypoxia was no longer needed. Heald left the Royal Air Force when he became unfit for overseas service and transferred to the world of civil aviation, becoming for a while the Secretary to the Medical Committee of the ICAO. The standards and examinations that he had fought for became the foundation for civilian medical examinations for aircrew. Thus the medical standards and the basic medical examination for aircrew established by the pioneers of 90 years ago, would still be recognised by their counterparts in the RAF Medical Branch today.

Notes:

1 Wells, H V; 'Some aeroplane injuries and diseases, with notes on the aviation service', *JRNMS*, 1916, Vol 2, pp65-71.

2 Wells, H V; *op. cit.*

3 Wilbur, F I; 'Aviation and common sense', *Flight*, 1911, Vol 3, pp399-400.

4 Alder, J E; 'Some notes on the medical aspect of aviation' in Hamel, G and Turner, C C, *Flying – Some Practical Experiences* (London, Longman, Green & Co, 1914).

5 Wells, H V; 'The flying service from a medical point of view', *JRNMS*, 1915, Vol 1, pp55-60.

6 Dépagniat, M R; *Les Martyrs de l'Aviation* (Paris, E Bassett et cie, 1912).

7 Holden, H C L; 'Lessons accidents have taught', *The Aeronautical Journal* 1914, Vol XVIII, pp204-11.

8 Watson-Cheyne, Sir W; Letter to General Smuts, dated 8 January 1918 in Heald, C B, *Genesis of aviation medicine in the Royal Flying Corps and Royal Air Force*, National Archives, Cabinet Office Historical Section, 1965.

9 Munday, R C; Letter to Sir Walter Fletcher, dated 18 January 1918. National Archive FD5/31.

10 Lyster, T C; 'The aviation service of the medical department of the Department of the Army', *Annals of Otology, Rhinology & Laryngology*, 1918, Vol 27, pp851-5.

11 The Better Regulation of Chimney Sweepers and their Apprentices Act 1788, 28 Geo 3, c48.

12 Ellenbog, U; *Von den Giftigen besen empffen und Reuchen* (Augsburg, M Ramminger, 1524).

13 Von Hoehenheim, T P A B; *Von der Bergsucht und anderen Bergkrankheiten* (Dillingen, Sebaldum Mayer, 1567).

14 Ramazzini, B; *De morbis artificum diatriba*, 1700. (Translated by Wright, W C; Chicago, University of Chicago Press, 1940).

15 James, A W H; *RAF Quarterly*, 1930, Vol 1, pp534-8.

[16] Heald, C B; *Genesis of aviation medicine in the Royal Flying Corps and Royal Air Force*, National Archive, Cabinet Office Historical Section, 1965. Much of the information in the remainder of the paper draws on Heald's account.

[17] *Ibid.*

[18] Atenstaedt, R L; 'The organisation of the RAMC during the Great War', *Journal of the Royal Army Medical Corps*, 2006, Vol 152, pp81-5.

[19] Royal College of Physicians. *Munks Roll*. Vol VI, pp231-2.

[20] In Heald's account, he was not sure of the name but thought that the officer was a Temporary Captain Anthony of the Buffs. The list of officers serving in No 20 Sqn does not list anyone of that name from the Buffs although there is a Captain R F Anthony from the Welsh Regiment.

[21] Barker, R; *The Royal Flying Corps in World War 1* (London, Robinson, 2002) pp 223 & 278.

[22] Birley, J L; Letter to Sir Walter Fletcher dated 4 March 1917. National Archive, FD30.

[23] The figures 6/9 means that the candidate has to be able to see at 6 metres what a person with normal vision would see at 9 metres. 6/6 is 'normal' vision although many successful pilots achieve 6/4.

[24] Undated paper on visual standards, author unknown. National Archive FD5/35. From its position in the chronologically arranged archive, the date should be April 1917.

[25] Lister, Col; Reported by Maj Birley in letter to Maj Heald dated 13 Mar 17. National Archive FD5/35.

[26] Munro, Sir D; *It passed too quickly* (London, Routledge, 1941) p226.

[27] Livingston, Sir P; *Fringe of the Clouds* (London, Johnson Publications, 1962) pp126-7.

[28] Undated blank forms 1 and 2. Form 1 is for recording history whilst Form 2 is for physical examination. National Archive FD 55/35.

[29] Fletcher, Sir W M; Letter to Capt C B Heald dated 27 March 1917. National Archive FD5/35.

[30] Henderson, Sir D; Letter to Sir Walter Fletcher dated March 1917. National Archive FD30.

[31] Whittingham, Sir H E; Personal communication, 1980.

[32] Munro, Sir D. *Op. cit.*

[33] Flack, M; 'Tests for flying efficiency and flying strain' in *The Medical Problems of Flying*, Special Report No 53, London, Medical Research Council, 1920.

[34] Medical Research Council. *The Medical Problems of Flying*, Special Report No 53, London, Medical Research Council, 1920.

[35] Anderson, H G; *The Medical and Surgical Aspects of Aviation* (Oxford, Oxford University Press, 1919).

THE RAF INSTITUTE OF AVIATION MEDICINE 1945-1994 CONTRIBUTIONS TO AVIATION AND FLIGHT SAFETY

Air Vice-Marshal John Ernsting

John Ernsting qualified in Physiology (1949) and Medicine (1952) at Guy's Hospital and was commissioned into the Medical Branch in 1954. He spent the whole of his service career (1954-1993) at the RAF Institute of Aviation Medicine (IAM). He was head of the Altitude Division 1957-1977, then Deputy Director and Director of Research and finally Commandant. On retiring from the RAF John Ernsting moved to King's College London where he teaches and conducts research in human and aviation physiology. He is the Honorary Civil Consultant in Aviation Medicine to the RAF, aeromedical adviser to BAE Systems, a Fellow of the Aerospace Medical Association and a Past President of the International Academy of Aviation and Space Medicine.

INTRODUCTION

In the thirty-nine years of its existence (1945-1994) the RAF Institute of Aviation Medicine (IAM) rapidly became recognised internationally as the centre of research and education in aviation medicine in the United Kingdom serving both military and civil aviation. The formation of an Institute to continue and to expand the work which had been conducted by the RAF Physiological Laboratory during World War II was proposed by the Director General of Medical Services (RAF), Air Marshal Sir Harold Whittingham, in 1943. The newly built RAF Institute of Aviation Medicine which was built in the south east corner of Farnborough airfield was opened by the Princess Royal on 30 April 1945. The Institute ceased to exist on 1 April 1994 when, as part of the reorganisation of defence research, it became the RAF School of Aviation Medicine which was destined to be closed in 1998 when a part of it was transferred to Royal Air Force Henlow to form the RAF Centre of Aviation Medicine.

The Legacy of the Second World War

The urgent need for applied research into the effects of aviation environments upon aircrew, and the development of procedures and equipment to protect them against these effects, was recognised in the United Kingdom in 1937 and 1938. It led to the formation in March 1939 of the Flying Personnel Research Committee (FPRC) to advise the Secretary of State for Air on ‘the medical aspects of all matters concerning personnel which might affect safety and efficiency in flying.’ A very early decision of the FPRC was that the RAF Physiological Laboratory should move from Royal Air Force Hendon to the Royal Aircraft Establishment (RAE) at Farnborough. Dr Bryan Matthews was seconded from Cambridge University to form the Physiological Laboratory at the RAE. A very effective applied research organisation was rapidly established with Bryan Matthews as its head.

The Physiological Laboratory made major contributions to the safety and efficiency of service aircrew during World War II but with demobilisation most of the medical officers returned to civilian posts. Two RAF medical officers Sqn Ldr William K Stewart, who had been posted to the Laboratory in 1940, and Sqn Ldr Henry L Roxburgh, who had joined the Laboratory in 1941, elected to remain in the RAF and both spent their entire subsequent Service careers at the Institute. Sqn Ldr Stewart was appointed Head of the Institute in 1946, a post which he held until his death, at the early age of 54 years, in 1967 shortly after attaining the rank of air vice-marshal. Bill Stewart was an inspirational leader

The RAF Physiological Laboratory was accommodated in the annex alongside one of Farnborough’s famous ‘black sheds’.

(Left) Air Vice-Marshal William K Stewart CB CBE AFC MRCP (1913-1967). Commanding Officer, RAF IAM 1946-1967. (Right) Air Vice-Marshal Harold L Roxburgh CBE PhD FRCP (1909-1987) RAF IAM 1946-1974, Commandant from 1967.

whose abilities and contributions as an aviation physiologist were widely recognised, both nationally and internationally, especially in the United States and Canada. He was also a first class planner and politically astute. Harry Roxburgh served as Stewart's deputy until, following Stewart's death, he was appointed Commandant, a post which he held until he retired in 1974 in the rank of air vice-marshal. Like Stewart, Roxburgh was well known in aviation medicine circles. These two men brought the ethos and successes of the wartime Physiological Laboratory to the new Institute of Aviation Medicine.

RAF IAM Facilities

The new Institute, in 1945, had good laboratory and office space and housed the hypobaric and cold chambers which had been part of the wartime Physiological Laboratory. It also had a new pool for floatation experiments. The first major facility to be added to the IAM was a large and versatile climatic laboratory which was commissioned in 1952. It was followed in 1955 by a man-carrying centrifuge with an

18.2 metre-long arm carrying free swinging gondolas at each end. A high performance hypobaric chamber, capable of simulating altitudes up to 150,000 feet, was installed in a new building (the West Wing) in 1963. Further additions to the Institute's capital facilities were a combined climatic and hypobaric chamber (temperature range -60° to +145°C at altitudes up to 60,000 feet), a 40G decelerator track, an advanced helmet impact test facility and a vibration laboratory. A new three-floored building (the North Wing) to house the expanding psychology and special senses research groups, including an advanced research flight simulator, was occupied in 1974. The Neurosciences Division, which housed the animal facilities, was further expanded in 1975 to include a sophisticated sleep laboratory. Finally, the Institute, throughout its existence, had RAF fixed-wing aircraft on its inventory. These included at various times a Spitfire Mk 9, a Piston Provost, a Meteor T7, a Canberra B6, a Hunter T7 and two Hawk T1s.

The Staff of RAF IAM

The professional staff of the Institute in 1945 comprised seven RAF medical officers and four civilian scientists. Recruitment of staff to perform the basic and applied research and teaching tasks of the Institute was greatly eased by the continuation of National Service. The many links which Bill Stewart had with British Medical Schools resulted in newly qualified doctors who were planning to enter research serving at IAM. The importance of a cadre of able, medically qualified physiologists to the research and teaching activities of the Institute was recognised by rapid expansion in the 1950s of the RAF Speciality of Aviation Physiology, consultant status in which was gained by on-the-job training at IAM, and the award of the PhD degree. A second, more applied, speciality, Aviation Medicine, was formed in 1968; in 1975 the two were combined to form the speciality of Aviation Medicine which had, in the years after 1975, a total strength of fourteen to sixteen medical officers, of whom six to seven were consultants. The members of the speciality were employed at IAM. The military medical officers on the staff of the Institute included a group who were also experienced pilots (termed Flying Personnel Medical Officers – FPMOs – until 1975 when they were renamed Medical Officer Pilots). This group operated the Institute's research aircraft, maintained links with the operational Commands and were often specialists in cockpit ergonomics.

The civilian scientific staff also increased considerably over the first twenty years of the existence of IAM by recruiting psychologists, physiologists, physicists, electronic engineers and mathematicians. A few civilian medical officers were also appointed to the staff. The technical staff was expanded with the formation of a drawing office and mechanical engineering and electronic workshops. The total staff in the Institute peaked in the late1960s at 240, of whom one third were RAF personnel and two thirds were civilians. By the early 1990s the total number of staff had fallen to 180.

CONTRIBUTIONS TO AVIATION

The Institute made extensive and far-reaching contributions to aviation by researching the effects on humans of the environments associated with flight and developing methods of enhancing the performance of aircrew and the safety of air operations. Its activities embraced military aviation, principally of the Royal Air Force but also of the Royal Navy and the Army Air Corps as well as civil aviation. Some of these contributions are described in this paper.

Altitude and Altitude Protection

The effects of exposure to altitude and the basic requirements of protection against hypoxia and decompression sickness were well recognised during World War II. The planned high-altitude role of future combat aircraft, such as the Canberra, the V-bombers and the Lightning, however, generated the need for emergency protection in the event of loss of cabin pressure or escape at high altitude. A number of USAF capstan partial pressure suits were purchased from the US in 1951 to support test flying above 50,000 feet. IAM fully evaluated the performance of the capstan suit at altitudes up to 60,000 feet and trained flight test crews in its use. They were worn by Walter Gibb and his navigator when they gained the world altitude record of 63,668 feet in a Canberra in 1953. The evaluation of the capstan suit by IAM demonstrated, however, that the suit restricted movement and did not integrate well with British ejection seats. The Institute advanced the concept of a minimal-coverage suit which would provide adequate ‘get-me-down’ protection and yet not unduly encumber the wearer. The system comprised an oxygen-inflated bladder which

Partial Pressure Helmet and Pressure Jerkin developed by IAM for high altitude protection in the Lightning.

applied counter pressure to the trunk (the pressure jerkin) and inflation of the standard anti-G suit to apply counter pressure to the lower limbs, leaving the upper limbs free of pressure clothing. The concept was welcomed by the Air Staff and the pressure jerkin-G-suit combination was developed by IAM. The pressure jerkin assembly, together with a UK partial pressure helmet, replaced the capstan suit for test flying in 1956. The assembly was adopted for the Lightning. A sleeved version of the pressure jerkin was also developed to provide 'get-me-down' protection from 100,000 feet for application to the Saunders Roe SR53. The performance of this assembly was assessed in a series of decompressions to a pressure altitude of 100,000 feet by a team from IAM in the hypobaric chamber at the Canadian Defence Medical Research Laboratory at Downsview, Ontario in 1956. During this series of decompressions one subject, the author, was decompressed to an altitude of 140,000 feet.

The oro-nasal pressure demand oxygen mask (RAF Type P/Q) developed by IAM and the Chemical Defence Establishment (CDE) at Porton Down in the early 1950s was found to have excellent high pressure sealing properties. An extensive research programme conducted by the Institute demonstrated that this mask, used with the pressure jerkin and anti-G suit, gave very satisfactory 'get-me-down' protection from 56,000 feet. The latter assembly was adopted for high altitude protection in the Vulcan B2, Victor B2 and Canberra PR9. A later development of the assembly by IAM, RAE and industry, the

An instrumented subject (in this case, the author) about to be decompressed breathing air from 8,000 to 38,000 feet in the High Performance Hypobaric Chamber.

combined partial pressure suit, entered service in the RN Phantom in the late 1960s.

It was recognised that the introduction of partial pressure suits into the Royal Air Force would require the establishment of an aircrew training centre manned by specially qualified staff. The RAF Aviation Medicine Training Centre (AMTC) was therefore established in 1959 at RAF Upwood with staff trained by IAM. AMTC moved to RAF North Luffenham in 1962 and, with supervision by IAM, became the centre for the training of all RAF aircrew in aviation medicine and the use of their personal equipment.

The extensive experience of the effects of flying at altitudes up to 10,000 feet without supplemented oxygen gained in World War II led to international agreement that the maximum cabin altitude of commercial passenger aircraft, in which crew and passengers breathed air, should be set at 8,000 feet. Squadron Leader David Denison and Frank Ledwith at IAM showed in 1965, however, that breathing air at 8,000 feet, and even at 5,000 feet, produced a significant impairment in the performance of novel tasks. This finding led to the recommendation that the cabin altitude in Concorde should not exceed 6,000 feet. Controversy continues to this day as to the maximum cabin altitude which should be permitted in commercial passenger aircraft. Whilst the international standard remains at 8,000 feet, it is very likely that the maximum cabin altitudes of the next generation of commercial aircraft will not exceed 5,000 feet.

The adoption in the V-bombers of a ‘routine’ maximum cabin altitude of 8,000 feet and the advent of commercial aircraft flying at altitudes up to 38,000-40,000 feet led to extensive studies at IAM of the severe hypoxia which is produced by rapid decompression to these altitudes whilst breathing air and its subsequent correction by breathing 100% oxygen. These studies led by the author and David Denison produced the detailed requirements for the delivery of oxygen in these circumstances which formed the basis of the regulations on the use of oxygen in military and civil high altitude aircraft in which air is breathed routinely in flight.

The possibility that a failure of pressurisation of the cabin might occur in Concorde when flying at 60,000 feet, together with the time required for the aircraft to decelerate and descend to below 15,000 feet, led IAM to study the effects of the cabin altitude – time exposure predicted by the aircraft designers for a rapid decompression at 60,000 feet – upon passengers who were breathing air throughout the exposure. Squadron Leader Tony Nicholson and the author conducted a series of decompressions of non-primates which suggested that the most severe decompression profile predicted by the manufacturer would cause gross brain damage in, or death of, passengers who were breathing air. These studies led to a reduction in the size of the windows in the cabin and additional measures to reduce the likelihood of a failure of the cabin outlet valves in the open position.

The pressure demand oxygen delivery systems introduced into the RAF in the early 1950s, which were of American design, imposed significantly higher resistance to breathing than the economiser system which they replaced. Furthermore, failures of oxygen regulators, in which the demand valve controlling the flow of oxygen seized in the closed position, so that the pilot breathed cabin air, resulted in several incidents of severe hypoxia, and the death of a pilot. IAM recommended that the air entry port of the oxygen regulator should be closed so that the pilot would be unable to breathe in the event of a failure of the demand valve. Whilst this procedure ensured that aircrew would have an immediate warning of the possibility of hypoxia, the breathing of 100% oxygen gave rise to a high incidence of chest discomfort and coughing following exposure to +Gz accelerations in flight – a condition which became known as ‘Hunter Lung’. The Institute conducted laboratory and field studies in the early 1960s which revealed that exposure to +Gz whilst breathing 100% oxygen results in collapse of the lower parts of the lungs. Experiments demonstrated that this lung collapse could be prevented by breathing gas containing 40% nitrogen. This requirement was subsequently embodied in the international standards for the oxygen systems of combat aircraft. The Institute continued to emphasise the need to reduce the breathing resistance imposed by oxygen systems. It conducted, using its Hunter T7, extensive measurements of the breathing demands of pilots in flight, including aerobatics and mock air-to-air combat, which led to progressive improvements to the specifications for military oxygen systems. Based upon the IAM research, a high standard of performance had been defined in MOD specifications by 1975. These specifications were met by UK industry as exemplified in the oxygen systems for the Hawk and Tornado. The physiological requirements on which the MOD standards were based were subsequently incorporated in ASCC and NATO standards. The knowledge and experience gained by UK manufacturers in meeting the MOD specifications placed them in a strong position when they bid for contracts to provide oxygen equipment for American military aircraft.

The significant operational penalties arising from the need to replenish the oxygen store of a combat aircraft between sorties, and the logistics of supplying liquid oxygen, led to the investigation of methods of generating oxygen on board aircraft. On Board Oxygen Generating Systems (OBOGS) using synthetic molecular sieves to produce oxygen-rich breathing gas from engine bleed air were developed in the US and UK in the late 1970s and early 1980s. A prototype molecular sieve oxygen concentrator (MSOC) system, developed by Normalair-Garrett Ltd (NGL) in the UK, was assessed in the laboratory and in flight by the Institute, the system being installed in the IAM Hunter T7. These evaluations, which demonstrated the high standard of performance of the NGL system, supported the successful bid by this manufacturer to supply the MSOCs for the USAF's B-1B Lancer.

The US manufactured MSOC for the AV-8B was also to be fitted to the RAF's Harrier GR5. The author spent a sabbatical year at the USAF School of Aerospace Medicine (SAM) at the time when the School was assessing the performance of the MSOC for the AV-8B, and the knowledge which he gained then supported the IAM advice to MOD on the shortcomings of this MSOC. The Institute proposed and developed a breadboard model, using the US oxygen concentrator, which overcame the deficiencies of the US system. The IAM modifications to the US system were developed for the Harrier GR5. The fully developed system was assessed by the Institute in the laboratory and then installed in the IAM Hunter T7 where its excellent performance was demonstrated in forty-three flights. A fully integrated programme to study the effects of bleed air contaminants and chemical warfare agents upon MSOCs was developed and managed by IAM and USAF SAM during the 1980s.

The IAM continued to provide extensive advice to MOD and to British Aerospace in the1980s relating to proposals to install MSOCs in other aircraft, including the Tornado. It also played a major part in the development of the design and specification of the MSOC for the European Fighter Aircraft, conducting experimental studies of methods whereby an MSOC could provide pressure breathing on exposure to high +Gz accelerations and to high altitudes.

Sustained Accelerations and G Protection

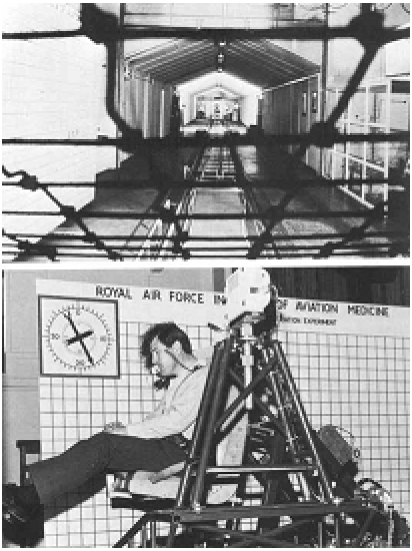
The outbreak of the Korean War in 1950 when the speed and manoeuvrability of the MiG-15 and F-86 Sabre led to pilots being exposed to high G in dog-fights stimulated the UK to develop G valves and anti-G suits. Intensive programmes to develop a UK anti-G system were commenced by RAE, IAM and UK manufacturers, with the IAM FPMOs conducting the in-flight evaluations of the systems in the IAM's Spitfire, Meteor and Vampire with repeated exposures to +Gz accelerations up to 8G. This programme yielded the first UK G valve, which was introduced into service with the Hunter, and several versions of anti-G suits. Development of G valves and conventional anti-G suits continued throughout the 1960s and 1970s with the Institute conducting studies on its man-carrying centrifuge, in the IAM aircraft and in RAF squadrons.

Another approach to increasing G tolerance considered in the immediate post-war period was for the pilot to be in the prone position, which greatly reduced the 'vertical' distance between the heart and the brain. Aircraft designers were also looking at ways to reduce the frontal area of new jet aircraft. Placing the pilot in the prone position was a possible way of doing so. A Meteor Mk 8, modified to accommodate one pilot in the prone position whilst the other sat in a conventional seat, was provided in 1954 for evaluation

Air Vice-Marshal Peter Howard CB CBE PhD FRCP (1925-2007), who served with the RAF Institute of Aviation Medicine, 1951-1988, as Commandant from 1975, seen here as a squadron leader experiencing 7G at first-hand on the IAM's centrifuge at Farnborough in 1958.

by the Institute. Ninety-nine sorties were flown by Wg Cdr Pat Ruffell-Smith and his team. Whilst the G tolerance of the prone pilot was considerably increased, the prone position was very uncomfortable in turbulent conditions, and visual fields, both internal and external, were limited. These findings, and other aircraft design considerations, resulted in the prone position being abandoned as an acceptable method of increasing G tolerance in flight. In the 1970s IAM investigated the value of an alternative posture – reclining the pilot backwards – as a means of increasing G tolerance. Experiments by Wg Cdr David Glaister demonstrated that reclining subjects back 60° from the upright posture only increased G tolerance by about 2G. Such a large degree of reclination would, however, impair forward vision and reduce essential panel space in the cockpit. This approach was also abandoned.

The commissioning of the man-carrying centrifuge in 1955, with its advanced physiological measurement systems, enabled Sqn Ldr Peter Howard to explore, in depth, the mechanisms responsible for blackout and the cardiovascular responses to +Gz and -Gz accelerations. By the early 1960s, these studies had provided an understanding of the ways in which vision can be maintained on exposure to high +Gz. They formed a basis on which future protective systems were developed by the Institute. Studies by Sqn Ldr David Glaister in the 1960s led to the proposal that pressure breathing, together with the anti-G suit, could be used to raise G tolerance without the intense fatigue produced by the standard anti-G straining



(Above) A view of the improved decelerator track and (below) Wg Cdr David Reader undergoing a 9G impact.

manoeuvres. The great potential value of pressure breathing with G (PBG) was amply confirmed by a joint RAF IAM/USAF SAM study in 1972. Flight trials of PBG conducted in the IAM Hunter T7 between 1975 and 1980, and in the IAM Hawk in the mid 1980s, when the PBG system developed by IAM was flown by RAF instructor pilots at a Tactical Weapons Unit provided overwhelming evidence of the effectiveness and acceptability of PBG. IAM and USAF SAM conducted an integrated programme which demonstrated that PBG with counter pressure to the chest and G suit would maintain full vision of the seated subject exposed for several minutes to +9Gz. The system was introduced by the USAF into the F-16 in order to reduce the incidence of G induced loss of consciousness. In the UK it was adopted for the European Fighter Aircraft. The Institute provided the specification for the PBG system and conducted extensive testing, both on the centrifuge and in the IAM’s Hawk, of the development life support equipment produced by industry to provide PBG for the Typhoon.

Short Duration Accelerations

The short duration, high intensity accelerations experienced during crash impact of an aircraft and escape from an aircraft in flight can cause severe or fatal injuries. The Institute proposed and evaluated improvements to restraint and parachute harnesses throughout the 1950s and 1960s. This research was hampered initially by the absence of a suitable test facility. In 1967 however the Institute designed and built its 40G decelerator track. An improved decelerator track was commissioned at IAM in 1970. These facilities allowed the Institute to develop and evaluate numerous improvements to the impact performance of aircrew and passenger seats and restraint harnesses. Of note was the development by Wg Cdr David Reader of the Simplified Combined Harness for ejection seats and of the negative G strap by Gp Capt Tony Barwood. The track was also used frequently to test the seats and restraint harness of both fixed- and rotary-wing aircraft which had failed in accidents.

The head, and particularly the brain, are especially susceptible to damage by the short duration accelerations produced by aircraft crashes and escape from aircraft. The Institute was closely involved in the provision of impact and wind-blast protection to the head from the development of the first protective helmet for aircrew (Mk 1 helmet) by IAM in 1951 to the assessment of the Type 10 ALPHA helmet (Advanced Lightweight Protective Helmet for Aircrew) in the 1990s. David Glaister played a major part in specifying the impact performance required of aircrew helmets. He also developed tests of the impact performance of helmets which became UK national test standards. Group Captain Glaister also pioneered the technique of assessing the impacts which had been received by a helmet during a crash or ejection and relating them to the injury which had been suffered by the wearer. The results of this programme made a major contribution to deciding the difficult compromises between the mass of a helmet, its comfort and the level of impact protection which it provided.

Ejection Seats

The history of the development of ejection seats in the UK is almost solely that of the work of the Martin-Baker Aircraft Company from 1945 when the requirement for ejection seats in RAF aircraft was first raised. Throughout the existence of IAM there was a very close symbiosis between the Martin-Baker Aircraft Company and the Institute with the latter providing physiological and medical advice to the Company. In the late 1940s a succession of medical officers, led by Bill Stewart, acted as subjects on the ejection tower in joint studies to determine the maximum acceleration and jolt to which the ejectee should be exposed. The Institute provided, throughout its existence, physiological analysis of, and advice on, the performance of Martin-Baker ejection seats. As aircraft speeds increased, along with the need to provide, in addition, safe ejection from aircraft at very low forward speeds (in the hover!) James Martin applied rocket propulsion to the ejection seat. Again the IAM was closely involved in providing physiological advice to Martin-Baker. The latter culminated in Sqn Ldr Peter Howard making the first rocket-assisted ejection in March 1962 when he fired himself from the rear of a modified Meteor T7 flying at 250 knots at 250 feet. The ejection was fully satisfactory – Peter reporting that the greatest hazard of the whole venture was the risk of hitting Mr Martin's car which was speeding towards his landing site!

Squadron Leader David Fryer conceived and conducted a novel experimental study of the effects of the high forces applied to the limbs on exposure to the wind-blast of an ejection. Employing the fact that water is 26 times as dense as air, David exposed himself and Roy Needham to speeds up to 22 miles/hour in water (equivalent to an air speed of 520 knots) using the underwater centrifuge at the Admiralty Research Laboratory at Teddington. IAM continued to advise Martin-Baker on the design and testing of limb restraint systems with Wg Cdr Peter Gill and Surgeon Commander Peter Beck playing a major role in the development of the arm restraint system of the Mk 10 seat for the Tornado.

Thermal Stress and Protection

From the beginning of aviation, thermal stress – whether it be from the low temperatures of the upper atmosphere or the high temperatures of hot countries or high speed low level flight – has always been a potential threat to the performance and survival of the aviator. Furthermore the requirement to wear functional clothing, such as partial pressure suits, G-trousers, immersion suits and, more recently, NBC suits, has increased the thermal strain experienced by military aircrew. Indeed even now one of the commonest comments by aircrew operating high performance combat aircraft is of thermal discomfort. In the late 1940s the Institute worked on protection against the cold, both in flight and on the ground, with IAM medical officers participating in survival exercises in the Canadian Arctic and Norway, a practice which continued into the late 1960s. The development of acrilan pile material led to the design of the 'Bunny Suit'. The excellent thermal insulation provided by this garment was confirmed by tests at IAM and the garment was introduced into the RAF. The inadequate heating of the cabins of several RAF aircraft, and the development of the full pressure suits, led Sqn Ldr John Nelmes to investigate in 1960 maintaining body temperature in cold environments by passing hot air over the skin by means of a piped suit. He found, however, that at an ambient temperature of -40°C that it was not possible to provide sufficient heat to the limbs without overheating, or even burning, the skin of the trunk and this technique was abandoned. John Nelmes later developed, and tested in the laboratory and in a Canberra, a one-piece elasticated suit made of wire and terylene yarn knotted together to replace the World War II electrically heated suits.

In 1949 Sqn Ldr Tony Barwood constructed an air ventilated suit (AVS) which he demonstrated, using the IAM hot room. It markedly reduced the thermal strain produced by a hot environment. A prototype AVS with an ice-cooled supply of engine bled air was installed in the IAM's Vampire 5 and a successful flight trial was conducted at RAF Khartoum in May 1950. By 1954 the AVS Mk 1 was in service in Canberras and Venoms. Following work at IAM, it was replaced by the improved AVS Mk 2 in 1958. Research by Dr David Kerslake and Sqn Ldr John Billingham in the 1960s demonstrated, however, that cool air was more effective than dry warm air in reducing heat strain. IAM then proceeded to develop the AVS Mk 3 for convective cooling. An air supply system for the Mk 3 was fitted to the Buccaneer in which the suit provided excellent thermal comfort. The AVS Mk 3 was also selected for the Multi-Role Combat Aircraft but was later deleted from the aircrew equipment, following cuts in defence expenditure.

Using a liquid, rather than air, to remove heat from the skin was first proposed by Sqn Ldr John Billingham in 1959. The concept was advanced by Des Burton of the RAE who proposed circulating the cooling liquid within tubes held close to the skin. Tests using a prototype Liquid Conditioned Suit (LCS) showed that the suit was very effective in removing heat in a hot environment and in delivering heat to the skin in the cold. Later prototypes LCSs were demonstrated to the American National Aeronautics and Space Administration (NASA). The LCS was adopted by NASA for thermal conditioning of the Apollo full pressure suit and was worn for the Lunar landings. Following an assessment by IAM, a very successful flight trial of the

LCS was conducted in a Vulcan in Cyprus in 1972. However, cuts in defence expenditure in 1973 prevented the LCS system being fitted to the Vulcan. The need to provide personal conditioning when aircrew were wearing NBC protective clothing increased the attractiveness of the closed system of the LCS, as compared with the need to supply air to the AVS which required large heavy filters in the air supply. The RAE reduced the coverage of the LCS in the late 1970s in order to reduce the thermal burden which it imposed when it was not conditioned. This development produced the Liquid Conditioned Vest (LCV), which tests by IAM showed gave good protection against heat stress. This garment was adopted for the European Fighter Aircraft. Thus, some forty-seven years after it was proposed, a thermal protective garment employing liquid in place of air in the form of the Liquid Conditioning Vest was to be introduced into RAF service with the Typhoon in 2007.

The physiological responses to hot and cold stresses were studied by IAM throughout its existence in order to provide a sound basis for the specification and design of protective systems. The control of sweat production and evaporation, the effect of dehydration on the tolerance of heat and the effects of acclimatisation to heat were amongst the topics investigated. The Institute also conducted studies of the effects of heat stress upon mental performance, some of which suggested that skin temperature and not core (deep) body temperature was the most important factor determining both comfort and performance in moderate heat stress.

A major contribution of IAM in the 1970s, to the quantification of the thermal stress experienced by aircrew under operational conditions, was the development of a series of Automatic Thermal Data Recorders (ATDR) for use in aircraft. These compact devices recorded dry bulb, wet bulb and black bulb temperatures and air flow, together with core and skin temperatures. The environmental sensor unit was mounted on the head box of the ejection seat. Core temperature was measured initially by a thermistor inserted in the ear canal and later by an expendable radio pill which the pilot swallowed. The ATDRs were used to record thermal conditions in the Harrier, Phantom, Buccaneer, Hawk and Tornado, as well as a variety of helicopters. The information gathered using the ATDRs allowed faithful simulation of the cockpit environment in the Institute's

Climate Chamber, for the evaluation of the thermal burden of various clothing assemblies and the effectiveness of AVS and LCS/LCV equipment.

The Institute was also closely concerned with the survival of aircrew and passengers on immersion in the sea. It continued, throughout its existence, to develop and evaluate improvements to life preservers and immersion suits and, in the late 1980s, it studied the problems arising during escape from immersed helicopters. Following the introduction of the two-piece ventile fabric immersion suit into the RAF in 1951, IAM and the manufacturer proposed, and the Institute assessed, major improvements, such as the single garment with a waterproof sliding fastener, the Immersion Suit Mk 8, which entered service in 1965. Finally the proposal to place immersion protection beneath the standard aircrew coverall led to the development of the Inner Immersion Coverall. The sizing, fit and immersion protection provided by prototypes of the garment were assessed by IAM and the considerably more comfortable garment was introduced into the RAF in the 1980s.

The Institute conducted experimental studies in the 1980s to define the levels of thermal insulation required to provide specified survival times in relation to the temperature of the water in which the survivor was immersed. In parallel, using a heated manikin, the immersed thermal insulation provided by various combinations of aircrew clothing worn beneath the Immersion Coverall was measured. The results of these studies, which were published in Aircrew Manuals, together with the range of available air-sea rescue services, allowed decisions to be made at squadron level as to the insulative clothing which should be worn by aircrew on a given sortie over the sea. This approach resulted in aircrew having to wear less insulative clothing on many sorties and thereby increased thermal and general comfort in flight.

The classic experimental study by Sqn Ldr Pask in 1944, of the floatation and self-righting properties of the Mk 1 life preserver, demonstrated conclusively that the design of this life preserver – an inflated bladder collar around the neck with the ends of the bladder reaching as far as the lower chest attached to a waistcoat fitted closely to the trunk – was very close to the ideal. Improvements to the basic life preserver made possible by the availability of synthetic fibres, the need to enclose the stole in a wind-blast cover to ensure that the bladder could not be damaged on high speed ejection and the requirements for a variety of survival aids, such as the personal location beacon and flares, to be mounted on the waistcoat occurred throughout the period from 1950 to 1990. IAM, led by Wg Cdrs Beaton and Gill, using human subjects, tested each modification to the aircrew life preserver, including automatic inflation of the stole and its performance when worn with the relevant clothing assemblies.

Integration of Aircrew with the Cockpit

A major area for research, which was conducted by the FPMOs of the IAM flight section, led by Wg Cdr Pat Ruffell-Smith in the late 1940s, arose from the many failures to integrate the pilot with his workspace which had occurred in World War II. The introduction of the ejection seat also necessitated changes to the cockpit workspace. The measurements of the body dimensions of 1,000 RAF aircrew, made by Morant in 1944, were used by the IAM team to determine the 'ideal' dimensions of the cockpit and ejection seat path and the position of controls and instruments within the cockpit. The work was conducted first using a skeleton cockpit of variable dimensions, and then using a cockpit mock-up in which controls and instruments could be positioned. The results of this work were accepted in full by the UK Cockpit Layout Committee. They were published in the UK Design Requirements for Service Aircraft (AvP970). The results were also accepted by the US services and led to the international military standards for cockpit design.

The Institute continued to provide advice and expertise on the dimensions of crew stations and on the positioning of controls and instruments and became the UK authority which assessed these aspects of all military aircraft in development and in service. By the late 1960s it was clear that the information on the body dimensions of RAF aircrew which had been gathered in 1944 required updating and expanding. RAE had developed improved techniques for measuring the sixty body dimensions required for the design of aircrew clothing and of aircrew workspace. A small team from Loughborough University which was directed by a RAE/IAM working party conducted a comprehensive survey of the body dimensions of 2,000 aircrew in 1970, the results of which were incorporated into AvP970.

The Aircrew Equipment Assembly produced for the RAF and RN Phantom

In the early 1960s, industry, principally ML Aviation, conducted the integration and testing of aircrew equipment assemblies (AEA), with IAM assessing the performance of the AEAs using human subjects. The arrangements for the development and assessment of AEAs underwent a considerable change, however, with the decision of the government in 1965 to purchase the F-4 Phantom and F-111 from the United States, following the cancellation of the contract for the TSR2. In 1965 a small team, which included the Air and Naval Staffs, Jack London of RAE and the author, visited industry, government establishments and units operating the F-4 in the United States. The team found that many features of the aircrew equipment used in USAF and USN F-4s did not meet RAF and RN requirements. Its recommendation, that a UK AEA, including a UK oxygen regulator and mask, a UK life preserver with an integrated harness, and a personal equipment connector (PEC) should be used in Royal Navy and Royal Air Force Phantoms were accepted by MOD. The very short time (three years) before the Phantoms were to be delivered to the UK led the MOD Aircrew Equipment Research and Development Committee (AERDC) to decide that the development and assessment of the integrated AEA for the RAF/RN Phantom should be led by IAM where the author was the Aeromedical Project Officer for the aircraft.

In the two years, from 1965 to 1967, an IAM/RAE team, with strong support from the MOD and industry, developed and assessed at the Institute fully integrated AEAs and ejection seat restraint and parachute harness systems for the RAF/RN Phantom. Major features of the assemblies were a torso harness, mounted in a life-preserver which employed a conventional UK inflatable stole, a chest-mounted oxygen regulator, a seat-mounted PEC, a combined partial pressure suit with air ventilation and G protection, and developed versions of UK anti-G suits and flying and immersion coveralls. IAM developed and conducted rigorous test procedures of the various AEAs at altitudes up to 60,000 feet, at ambient temperatures from -26° to +50°C, at sustained accelerations up to +8Gz, at impact decelerations up to 25G, on whole body vibration, and on parachute dragging on land and in water. The IAM/RAE team also conducted a full fitting trial of the complete AEAs which employed 200 RAF and RN aircrew. Various components of the AEA were flown in the IAM's Hunter T7. The UK AEAs were in production by the time that the F-4s arrived in the UK.

The very considerable success of the development programme for the Phantom AEAs established a pattern whereby the Institute, reporting to the AERDC, led the integration of AEAs into most of the future combat aircraft of the RAF. Thus, in the period from 1967 to 1970, IAM was involved with the UK AEA and escape capsule of the F-111K, during which Sqn Ldr David Reader developed a much improved seat mounted restraint harness which was adopted for the USAF and RAAF versions of the aircraft. IAM played a major role in the Working Party established by the AERDC in 1970 to provide integrated advice to MOD and the British Aircraft Corporation (BAC) on the personal equipment, associated supply systems, cabin conditioning and escape system for the Multi-Role Combat Aircraft. The report of the Working Party, published in December 1971, gave details of the basis of the advice on all these topics, as well as NBC protection. IAM advised BAC (Warton) on the specification of, and conducted many of the assessments using human subjects of, the AEAs, the escape system (especially arm restraint) and the oxygen, anti-G and personal conditioning systems. The Institute continued to conduct work for the MRCA throughout the 1970s, with the author chairing the UK/FRG/IT Committee on the Life Support and Escape Systems for the aircraft. IAM also conducted the assessment and integration of the German and Italian aircrew equipment with the ejection seat and cockpit of the MRCA, and was the major source of aeromedical advice to the Air Staffs of the three nations. Similar, very close, collaboration developed between British Aerospace and IAM in the latter half of the 1980s in relation to the development of the

European Fighter Aircraft with the IAM providing the aeromedical inputs to the specifications for the performance of AEAs, life support and escape systems.

Protection against NBC Warfare Agents

With the increasing concern of the Defence Staff that air operations would be very severely affected, if not stopped altogether, by enemy attacks using chemical and biological weapons on airfields, both in RAF Germany and the UK, the IAM and RAE, acting under the aegis of the AERDC, became the leading organisations for the development of aircrew NBC protective systems and associated operating procedures. These activities were strongly supported by the Chemical Defence Establishment (CDE) at Porton Down.

The first major contribution, which was made by Bob Simpson of the RAE and Wg Cdr Derek Beeton of IAM, proposed that the activated charcoal fabric layer of the ground forces overgarments should be worn beneath the standard aircrew flying coverall and immersion coverall. Following assessments by CDE that such a layering would provide adequate protection to the skin, the Aircrew NBC Inner Coverall was sized, integrated with AEAs and evaluated in laboratory trials at IAM and by field trials in RAF and Army flying units. The aircrew NBC Inner Coverall was in production for the RAF by 1973. It was subsequently purchased by the USAF, the US Marine Corps and the Canadian Forces.

Following the evaluation of the attempts by industry to produce an over-the-helmet Aircrew Respirator (AR No 2), the RAE designed an over-the-helmet respirator (the AR No 3) which mainly used available components of aircrew equipment and a breathing and hood-ventilating system developed by IAM. The Aircrew Respirator No 3 overcame virtually all the disadvantages of the earlier aircrew respirators developed by industry. It was not, however, compatible with weapon sights and Night Vision Goggles. Bob Simpson proposed, in 1976, an under-the-helmet respirator with its visor plate fitting within the facial opening of the aircrew helmet, which insured compatibility of the respirator with the aircrew helmet and visors, NVGs and weapon sights. The proposed Aircrew Respirator No 5 was immediately accepted by the Defence Staffs and the joint RAE/IAM team, working from 1976 to 1979, developed this aircrew respirator

The Aircrew Respirator NBC No 5 Mk 1.

in-house and assessed it using all the relevant test facilities and expertise of IAM. Two versions of the AR No 5 were developed. The AR No 5 Mk 1 included an oxygen supply to the mask of the respirator, which was fed by the medium pressure oxygen systems of the Phantom, Harrier and Jaguar. The AR No 5 Mk 2 was designed primarily for use with an NBC Portable Ventilator in helicopters and in fixed-wing aircraft in which it was possible to stow NBC Portable Ventilators, including the Nimrod, Hercules and VC10.

The development models of the AR No 5 were assessed in flight in the IAM Hunter T7 and in 1977 and 1978 formal trials, together with the below-the-neck components of the Aircrew NBC Assembly, were conducted in RAF aircraft in Germany and the UK. These trials included the formal doffing and donning drills required on entry into, and exit from, collective protection. The IAM flight trials, and the formal service trials, demonstrated a high level of acceptability of the AR No 5 and the other components of the NBC AEA, provided that the aircrew had worn the assembly for several sorties. The AR No 5 was then produced by industry with deliveries to the RAF and RN commencing in 1979.

The Institute defined the performance required of the oxygen and filtered air supplies for the AR No 5 Mk 1 and integrated and assessed the supply systems for the wide range of combat aircraft in which the respirator was to be employed, including the Phantom, Harrier, Jaguar, Buccaneer, Hercules and VC10. In response to the high level of urgency placed on the NBC protection of aircrew operating fast-jet aircraft in RAF Germany, an interim supply system for the AR No 5 Mk 1, requiring no modifications to the airframes, was proposed, developed and assessed by IAM in 1978 and 1979. The RAE and IAM conducted parallel trials of the AR No 5 Mk 2 and NBC AEA in RAF, RN and AAC helicopters and RAF transport aircraft.

RAE and IAM worked with CDE to develop facilities and procedures whereby contaminated NBC AEA could be safely doffed on entry to, and donned on exit from, areas of collective protection. These were tested using RAF aircrew subjects in a full scale mock-up built in the RAE. The results of these studies by the RAE/IAM team were incorporated in the updates of the Pilot Briefing Facilities in RAF Germany and the newbuild Squadron Operating Facilities in the UK.

This major effort by IAM and RAE resulted in UK military aircrew being provided with very effective and acceptable NBC protective systems by the early 1980s. The UK aircrew NBC assemblies were demonstrated widely to the NATO Air Forces, with the result that the AR No 5 Mk 2 was adopted by the US Marine Corps and the Canadian Forces. In the 1980s, IAM provided advice on, and conducted laboratory studies of, the operational use of aircrew NBC assemblies, in particular the alleviation of the heat stress imposed by the equipment and procedures and their effect upon sleep. One outcome of this most successful endeavour was that in the Middle East operation to relieve Kuwait, RAF fast-jet aircrew had fully proven and acceptable NBC protective equipment to wear in flight. Aircrew of other air forces (except those using the AR No 5) did not.

Accident Investigation

The IAM played a significant role in the analysis of the cause of the crashes of the two Comets which were lost in the Mediterranean early in 1954. The IAM team, led by Gp Capt Stewart, conducted independent examinations of the tissues from the bodies of the victims of these crashes, together with experiments using anaesthetised animals, to determine the mechanisms responsible for the injuries which had been found. Contrary to the findings of the Italian pathologists, the IAM team concluded that the extensive damage to the lungs of the passengers were not due to the effects of rapid decompression of the cabin of the aircraft, but were caused by the impact of the bodies with the sea. The work of the IAM team, which included two National Service medical officers, Flt Lts John Armstrong and David Fryer, exemplified the value of aviation medicine specialists, trained in research, to the investigation of the mechanism of injury occurring in aircraft accidents. It led to the formation, in 1955, of the RAF Department of Aviation Pathology and of a similar Department in the Armed Forces Institute of Pathology in the United States. Subsequently there was always close collaboration between the RAF Aviation Pathologists and IAM in the investigation of fatal aircraft accidents, both military and civil, with the Institute being concerned especially with the performance of restraint harness, seats and aircrew equipment on crash impact and ejection, and with how deficiencies in these equipments could be corrected. Much of the success of the IAM work in this field was due to the drive, energy and expertise of Gp Capt Tony Barwood, who established the IAM Accident Investigation Laboratory. Barwood studied, with great care and insight, the aircrew equipment and ejection seats which had been ejected from aircraft. He developed a high reputation in determining the causes of failures in this equipment and in devising ways of correcting the deficiencies which he had identified. The work of the Accident Investigation Laboratory was continued by Wg Cdr David Anton, whose investigation, using the Institute's decelerator track, of the mechanism of the pelvic and lower limb injuries sustained by the passengers of the Boeing 737-400, which crashed at Kegworth in 1989, led to a revision of the crash brace position for passengers.

Vision and Eye Protection

The late 1940s saw fighter pilots reporting difficulties in focusing their eyes when looking outside their cockpits at high altitude. The investigation of the difficulties of visual search in a totally featureless sky, by Flt Lt Tom Whiteside, who arrived at the IAM in 1948, led to the description of empty field myopia. He developed the visual search procedures required to overcome this phenomenon. Flight Lieutenant Bazarnick, a FPMO, and Tom Whiteside produced head-mounted anti-glare visor systems which overcame the deficiencies of the aircrew goggles. Following successful trials in the RAF, these visor systems were mounted on the Mk 1 protective helmets then under development by Surgeon Lieutenant Commander John Rawlins at the Institute. Tom Whiteside continued basic and applied research into vision in flight until the 1970s, when this task was inherited by Wg Cdr Derek Brennan. The recognition of the need for separate protection against glare, and protection of the eyes and face against damage by bird strikes during high speed, low-level flight, and by fragments of the canopy and wind-blast during ejection, led to the development of the inner, clear polycarbonate, and outer, tinted, visors of the dual visor system which were assessed by Brennan in 1976. Derek then conducted the very successful service trial of the dual visor system and the system was introduced into the RAF.

Squadron Leader Tom Whiteside conducted extensive studies in the 1950s and 1960s of the effects of the intense light produced by the explosion of a nuclear weapon upon aircrew vision. These investigations were conducted both in the laboratory and at the tests of the British nuclear weapons. He found that vision was restored in a brightly lit cockpit within a few seconds of exposure to very bright light and he confirmed effectiveness of the eye patch in preserving the vision of one eye in the event of a nuclear explosion. Whiteside also demonstrated the effectiveness of an electro-mechanical shutter which he had proposed and which had been constructed by the RAE. He used the device to protect his vision against the dazzle of the explosion of a nuclear weapon at Christmas Island in 1958 during Operation GRAPPLE. In later years, Derek Brennan evaluated the acceptability of vision through visors dosed with British-developed triple-state photochromic compounds. Unfortunately, whilst they provided good protection against nuclear dazzle, the rate at which normal optical density returned was too slow. In the 1980s, IAM integrated the American PLZT (lead lanthanium ziconate titanate) nuclear dazzle protective goggles with the AR No 5 assembly.

The recognition of the need for greater knowledge of the biological effects of lasers in the 1960s resulted in a programme at the Institute to determine the damage which could be done to the eyes of aircrew by laser weapons. The work, by Wg Cdrs Tony Nicholson and Derek Brennan, included studies of laser flash blindness and estimations of the ocular thresholds for several military lasers. IAM became the MOD authority for laser safety and the results of the experimental studies conducted at the Institute formed the basis of UK and international standards on the effects of laser radiation on vision and regulations such as safe viewing distances. IAM continued to provide advice on laser hazards and to assess laser protective visors under development for aircrew throughout the 1980s.

In 1972, Derek Brennan also led an experimental study at the CDE of the effects of the nerve agent Sarin upon the eyes of RAF volunteers and himself. This study led to the conclusion that the eyes of aircrew required a higher level of protection against the nerve agent than that required for ground personnel. The results of this study were incorporated in the UK specifications for aircrew respirators and into a NATO standard which defined the maximum acceptable dose of nerve agent to the eyes of aircrew.

The Institute, throughout its existence, was intimately involved in the development, assessment and integration of corrective spectacles for aircrew. Several major improvements to the design of corrective flying spectacles (CFS) were introduced by Derek Brennan in the 1970s. The acceptance of soft contact lenses in the general population, together with the limitations of CFS, especially their interactions with the aircrew respirator, led in the early 1980s to a joint study by the RAF Consultant Adviser in Ophthalmology and IAM of the acceptability of soft contact lenses for aircrew. Brennan directed studies of the performance of soft contact lenses at high altitude, high sustained +Gz accelerations, on whole body vibration and at extremes of environmental temperature. The results supported the approval of the use of soft contact lenses by RAF aircrew.

The major enhancement of vision by night vision devices, and the decision of the Defence Staffs to provide these devices in a wide variety of aircraft, involved the Institute in the major challenge of the increase in the mass of head-mounted equipment, both in normal flight and during escape. IAM also tested the visual performance of NVGs and associated cockpit lighting systems, especially during the flying programmes conducted by the RAE. The Institute developed a night vision training device, which was installed in the RAF Aviation Medicine Training Centre (AMTC), for the training of aircrew in the use and limitations of NVGs. Dr Alistair Macmillan continued to provide advice in the 1980s to the helmet and avionics manufacturers who were developing aircrew helmets with integral night vision enhancement devices.

Orientation and Motion Sickness

In 1957, Sqn Ldr Geoffrey Melvill Jones, then a FPMO at the Institute, conducted interviews with RAF squadron pilots to investigate ‘the current problems associated with disorientation in man controlled flight'. This survey of pilot experiences revealed that spatial disorientation occurred frequently in flight and led to the establishment at the Institute of basic and applied research on disorientation in flight. Melvill Jones himself conducted a series of high quality studies of the movements of the eyes during, and recovery from, spins in a specially instrumented Vampire T11, using a helmet-mounted camera to record the movements of his eyes. His studies were followed by many elegant investigations by Dr Alan Benson and his colleagues of the factors controlling the movement of the eyes and vision in a variety of motion environments. Their results contributed greatly to the present understanding of the ways in which misleading sensations are generated and vision is impaired by disorientating motions of flight. In order to correct the lack of awareness by aircrew of the limitations of their senses, Alan Benson revised aeromedical training requirements and designed and constructed a rotational device – 'The Spatial Disorientation Familiarisation Device (SDFD)' – to familiarise aircrew with some of the sensory limitations that are responsible for disorientation in flight. The first SDFD, which was installed at RAF AMTC in 1974, was found to be a very effective training aid and a second SDFD was installed in 1978.

The magnitude of whole-body vibration in rotary-wing flight, and the prediction that high speed flight at low level would produce marked oscillations of the aircraft, led to programmes at IAM to determine the physiological and performance effects of whole-body vibration. The programmes provided the biodynamic data on the transmission of linear and angular vibration to the head, which underpinned guidelines on the subjective tolerance of vibration. Experiments were also conducted on the visibility of displays when either the display or the observer was vibrated. In addition to providing valuable information on the deterioration of vision produced by specific vibration environments, the results of these studies pointed to the need for head-mounted displays to be space stabilised if visual acuity is to be preserved in the presence of head vibration at frequencies above 2Hz. Alan Benson gave advice on the specifications for helmet-mounted sights and displays and conducted evaluations of the performance of prototype system in motion environments.

Motion sickness in flight had been recognised during and after

The IAM's Hunter T7, XL563, which was extensively employed on trials work, including, PBG, the AR5 respirator, OBOGS for the Harrier GR5 and the measurement of pilots' breathing at the TWU.

World War II as a condition producing wastage in, and disruption of, flying training. Squadron Leader Tom Dobie developed and introduced desensitisation therapy for motion sickness into Flying Training Command in the 1960s. It involved ground-based and airborne phases, each with incremental exposure to increasingly provocative motion stimuli. The desensitisation programme was transferred to IAM in 1981 with the flying phase being conducted by a MO(P) in the Institute's Hunter T7. The introduction of active, rather than passive, motion and linear (on the IAM vibrator), as well as rotational, stimuli by IAM increased the rate and extent of the adaptation before the flying phase was begun. The programme was most successful, returning more than 80% of chronically sick aircrew to flying training and subsequently to operational squadrons.

At the same time that desensitisation therapy was being introduced, Dr James Reason developed at the Institute a neural mismatch theory of motion sickness which states that the condition is produced by motion which generates patterns of sensory input (especially from the eyes and the organs of balance) which are in conflict with those based on past motion experience. Reason's neural mismatch theory provided a common causation for all the situations where sickness is produced by motion (including flight simulators and space flight) and a mechanism for adaptation to unfamiliar motion environments. Subsequently, experiments conducted at IAM by Alan Benson and Rollin Stott refined the theory which is now almost universally accepted as explaining the production of motion sickness and adaptation to it.

Neurosciences

From the early 1960s the Institute conducted investigations of the workload and working conditions of civilian airline pilots. In 1965 a joint IAM/Ministry of Aviation team explored the ease with which subjective fatigue, heart rates and urine collections (for subsequent analysis of biochemical markers of stress) could be obtained from captains flying scheduled transatlantic sorties in BOAC Boeing 707s. The data was collected with ease. It demonstrated the value of heart rate as an indicator of 'stress'. The subjective comments of the pilots reinforced previous concerns with regard to the fatigue associated with local time changes and lack of adequate sleep before night time flights.

It was recognised that long-haul flights, involving crossing several time zones, together with irregularity of work and rest times, was leading to serious problems with the sleep of commercial aircrews. The FPRC accordingly set up the Flight Deck Workload Study Group in 1967. The IAM, led by Sqn Ldr Anthony Nicholson, conducted numerous studies of pilot sleep and performance, both in flight and in the laboratory in support of this study. Observation of the sleep patterns of airline pilots operating long-haul east-west routes led to the conclusion that the main problem in such aircrew was sleep disturbance, rather than sleep deprivation. The sleep patterns of aircrew involved in double-crew continuous flying operations in RAF Belfasts and VC10s were also studied in the late 1960s. These investigations emphasised the value of uninterrupted sleep by the resting crew and concluded that the optimum duration of the two-crew operations was about 48 hours. The IAM constructed sleep laboratories in which the effects of irregular patterns of rest and activity on the sleep and performance of subjects could be studied under controlled conditions. Experiments using a nine-day schedule of irregular rest and activity allowed the relationships between circadian rhythmicity, length of time on task and cumulative sleep loss to be examined. The observation that the sleep schedules of airline pilots included many short periods of sleep of three to four hours, and naps of around one hour, led the IAM to study, in the laboratory, the effects of short periods of sleep on the performance of subjects who were required to remain alert for long periods of time. The results demonstrated the value of a four-hour period of sleep before an overnight period of work. The studies of sleep in airline pilots were extended in the 1980s to collaboration with other international airlines and centres of aviation medicine in Europe and the United States. In these investigations the volunteer pilots slept before and after long haul flights in sleep laboratories, including that at IAM, where the quality of their sleep was recorded. The results of these various studies allowed Gp Capt Tony Nicholson and his group to develop by the late 1980s mathematical models of the performance of airline pilots as influenced by the interval between the end of the previous sleep and the commencement of duty, the duration of duty, the time of duty and the effect of changes in time zones (circadian rhythm). These models have been used extensively in the UK and Europe to assess whether projected work and rest patterns of aircrew schedules would be compatible with acceptable sleep and performance.

Wing Commander Nicholson and his colleagues also commenced studies in the mid-1970s of the acceptability of hypnotics to induce sleep in aircrew prior to duty. Many of the hypnotics used in clinical medicine were known to be very long-acting and to be administered in very high doses. The qualities of sleep and performance at an adaptive tracking task before and after sleep were investigated at IAM in volunteer subjects who were administered a variety of hypnotic drugs. These studies confirmed that most of the hypnotics in clinical use were unacceptable for inducing sleep before flying duty, as they impaired performance on the following day and that the effects of repeated doses were cumulative. However, the studies identified one hypnotic, Temazepan, which did not, at a dose which would ensure sleep, have any deleterious effects on performance after six hour's sleep. Furthermore there was no accumulation of the drug on daily ingestion. The use of Temazepan to ensure sleep by aircrew under well-specified conditions was approved by the RAF in 1980.

Temazepan was used most successfully to ensure that aircrew engaged in maritime reconnaissance and certain transport roles in the South Atlantic Campaign did not suffer sleep deprivation, in spite of the high mission rates and long duty periods required in order to meet operational requirements. The majority of aircrew took 20mg of

Temazepan to get to sleep at various times of the day. They experienced good sleep, without side or residual effects, and found that they could fly from six hours after taking the hypnotic without ill effects. The use of Temazepan greatly enhanced the ability of the aircrew to generate high levels of flying duty. Thus some transport crews achieved 150 flying hours within 24 days, which could involve six long-range missions lasting up to 28 hours. Some transport crews accumulated 360 flying hours within a three-month period. Maritime reconnaissance crews attained 100 flying hours within 14 days with flight durations of 6 to 20 hours. These crews were augmented with a pilot and an engineer. The provision of adequate sleep by the use of Temazepan and scheduling of flying duties was also used with considerable success in the high-workload transport operations which were performed during Operation GRANBY in 1990/91.

During the 1980s, IAM also addressed the problem of maintaining performance during intensive and sustained air operations which could last several weeks. The missions would inevitably involve prolonged duty overnight, when the coincidence of an extended period of work, with progressive circadian fall in alertness overnight, could result in very low levels of performance and even micro-sleeps. In these circumstances the administration of a suitable stimulant could, it was argued, prevent the fall in alertness and performance. Tony Nicholson and his team decided that the stimulant Pemoline was the drug of choice. Trials in the IAM sleep laboratories confirmed that the administration of a suitable dose of Pemoline after a six-hour sleep in the proceeding afternoon, which had been induced using Temazepan, successfully maintained alertness and performance throughout the following night. Simulations of several days of the irregular work and sleep which would arise in intensive sustained air operations in which Temazepan and Pemoline were administered to the subjects at appropriate times, suggested that it is possible to maintain a high level of alertness and performance over many days by the skilled and judicious use of these drugs.

Aviation Psychology

During World War II much of the research on matters such as the fatigue of aircrew, aircrew performance and the selection of aircrew were conducted under the guidance of the FPRC in the Department of

Psychology of the University of Cambridge. After the war, psychological research for the RAF was transferred to IAM where, as already described, work on cockpit ergonomics was performed initially by the FPMOs, especially Pat Ruffell-Smith. Beginning in 1949 a number of graduate psychologists joined the staff of the Institute. The principal interests of these researchers were in the presentation of information to pilots by aircraft instruments. Laboratory evaluations were carried out of proposed instrument displays of information, such as airspeed, aircraft attitude and altitude. The relative advantages and disadvantages of visual and auditory warnings were also investigated. IAM was a member of the UK Altimeter Committee (UKAC) which was set up in 1959 to recommend the design of a new altimeter to replace the, then universally used, three-pointer altimeter. There were numerous reports of pilots misreading the latter, sometimes with a near-fatal or fatal outcome. Laboratory studies, by John Rolfe at IAM, confirmed that there was a significant incidence of errors in reading the three-pointer altimeter. Discussions with the civil and military aviation organisation on the UKAC led to the conclusion that the new altimeter should comprise a digital display of altitude, together with a single-pointer with the latter revolving 360° once every 1,000 feet. John Rolfe then conducted extensive laboratory assessments of the speed and accuracy with which the new and existing displays could be read. These experiments demonstrated the absence of errors when the counter-pointer altimeter was used. These results were confirmed by trials in flight simulators and flight trials in BEA Vanguards and BOAC Comets, and the counter-pointer altimeter was subsequently fitted to both Service and commercial aircraft.

During the 1950s and 1960s IAM psychologists developed objective methods of measuring the performance of subjects exposed to various aviation stresses, including hypoxia, heat and vibration. Joint experimental studies of the effects of environmental stresses upon mental performance by psychologists and physiologists continued throughout the life of the Institute. These enabled IAM to provide definitive statements of the effects of these stresses, either alone or in combination, upon the performance of tasks closely related to the flying tasks of the aircrew. An ever-present problem was the measurement of fatigue. Squadron Leader Melvill Jones conducted an in-depth study in 1954 of the fatigue of aircrew involved in long range maritime reconnaissance in Shackletons, which suggested that a reliable indicator of fatigue was the subjective ratings provided by individual aircrew. It was certainly better than the various biochemical indicators which were measured during this study. Later research on aircrew fatigue was undertaken by the IAM psychologists and neuroscientists.

From the early 1950s, IAM was involved in providing psychological advice and research in support of air traffic control systems, both military and civil. Laboratory studies were conducted into the design and operation of radar displays. The results of these led to major improvements in the design of these displays. The Institute conducted trials in collaboration with the Royal Radar Establishment (RRE) at Malvern and the Air Traffic Control Evaluation Unit (ATCEU) at Hurn Airport, of various defence and air traffic control radar systems, such as LINESMAN and MEDIATOR. Collaboration with the ATCEU, RRE and the Civil Aviation Authority was led by David Hopkins of the IAM who developed an international reputation as an expert in the Human Factors of Air Traffic Control.

During the 1960s, IAM, led by John Rolfe, progressively improved the techniques employed in the assessment of cockpit displays. Methods of assessment, employing the Institute's research flight simulator, were perfected. Dr Rolfe was, for many years, the MOD expert on the human factors aspects of the design and use of flight simulators. The increase in the speed of aircraft, and the growth in the number and importance of cockpit instruments, in the early 1960s led Naish, of the RAE, to develop the Heads-Up Display (HUD). IAM, led by Joe Huddleston, contributed much by laboratory studies to the development and assessment of the configuration of the displays presented in the HUD. Human factors inputs to the design and assessment of cockpit displays and maps continued to be made throughout the life of IAM. Thus, in the 1970s, Roger Green conducted a study which demonstrated that the large number of auditory warnings proposed for the Tornado could result in confusion of the aircrew and incorrect responses. In the 1980s the IAM provided the human factors input to the specification and design of the airborne radar displays and ground stations of the Airborne Stand-off Radar (ASTOR) programme.

The importance of human factors in the causation of aircraft accidents was recognised by the Inspector of Flight Safety (RAF) in the late 1960s when Boards of Inquiry (BoI) were instructed to consider seeking the advice of an IAM psychologist (behavioural scientist). The value of the expertise of the IAM psychologist was rapidly appreciated by BoIs and the involvement of IAM to investigate the human factors aspect of accidents was firmly established in the RAF by 1972. For many years this task was fulfilled with great success by John Chappelow. He also developed a human error accident base at IAM. An important outcome of the involvement of an IAM psychologist in BoIs was the initiation of research projects at IAM with the aim of improving flight safety.

It had long been recognised that the mandatory reports of human errors by aircrew were usually only obeyed when disclosure was unavoidable, or when no punishment would follow. In an attempt to obtain more information on the mistakes made by aircrew, IAM proposed to the Civil Aviation Authority, the commercial airlines and the pilots' associations that a Confidential Human Factors Incident Report System (CHIRP) should be established whereby commercial aircrew could report to an independent agency, with assured anonymity, any incident that had implications for flight safety. CHIRP was initiated with the Institute, led by Roger Green, as the independent agency in 1982. The programme yielded some 400 reports in the first two years of its operation. Major topics to be reported were crew interactions and personality clashes on the flight deck, errors in the performance of flying skills and problems of fatigue. One dramatic report was by the captain of an airliner who woke during a transatlantic flight to find all the other members of his crew soundly asleep! The analysis of CHIRP reports by IAM led to many improvements to flight safety, including modifications to procedures and aircraft controls and changes to methods of selecting and training pilots.

Education

From its inception, IAM was responsible for the teaching of aviation medicine to RAF medical officers (MO). All MOs attended a two-week course in aviation medicine at the Institute as a part of their initial training in the RAF. Subsequently those medical officers taking permanent commissions were required to attend an eight-week course in advanced aviation medicine at IAM. It was apparent, however, by the early 1960s that the practice of aviation medicine on flying stations was unsatisfactory, with many permanently commissioned MOs having failed to attend the long course. The position was reviewed by a committee chaired by the PMO of Bomber Command (AVM Wilson) in 1964. This committee, of which Bill Stewart was also a member, recommended the formation of a cadre of MOs who had received training in academic and operational aviation medicine and who had attended a preliminary flying course. Subsequently these MOs were to receive regular continuation training at IAM. The recommendations of the Wilson Committee were accepted by MOD. It was decided that, on satisfactory completion of training, these MOs would be known as Flight Medical Officers (FMO) and that they would be awarded the FMO badge. The Institute developed, in collaboration with the Royal Navy, the Army and the Medical Departments of the Civil Aviation Authority and British European and British Overseas Airways, an academic course in military and civil aviation medicine. The first course, which lasted nine months, was held at the Institute in 1968/69. The Royal College of Physicians established a diploma in Aviation Medicine in 1970 and Air Vice-Marshal Roxburgh was appointed the first Whittingham Professor of Aviation Medicine at the College. The IAM course, the length of which was reduced to six months in 1970, was approved by the College. Over the ensuing decade, the Institute's course for the Diploma in Aviation Medicine (DAvMed) became established as one of the best aviation medicine courses world wide. Whilst the great majority of students on the course were RAF MOs, MOs from many overseas air forces, especially from Canada, Australia and New Zealand, as well as a few civilian physicians, attended with over 95% being successful at the examination for the DAvMed. Serving MOs from countries in the Middle East and Far East also attended the course. Within a year of the establishment of the DAvMed course, the Institute introduced a four-week course in aviation medicine and life-support and survival systems, which was attended by MOs from the British armed forces. Refresher courses in aviation medicine lasting two days were also held at IAM. These courses, not only provided continuation training, but were also a very effective means of bringing problems in aviation medicine, which the FMOs were encountering on flying units, to the attention of the research staff of the Institute. The cadre of FMOs trained by these courses at IAM greatly enhanced the practice of aviation medicine throughout the RAF. The text book for the DAvMed course, written principally by the staff of the Institute and RAF clinical specialists, and edited by RAF consultants in aviation medicine, was first was published in 1979. It, and subsequent editions (the fourth edition was published in 2006), became recognised world wide as a leading textbook on aviation medicine.

The Institute also became, in the late 1960s, the UK centre for teaching elementary aviation medicine to General Practitioners who wished to be appointed as Authorised Medical Examiners (AME) by the Civil Aviation Authority. This General Aviation Medicine Course (GAM), which was conducted jointly by IAM and the Medical Department of the CAA, was attended by many overseas physicians as well as doctors from within the UK.

Other short courses conducted by IAM included those for the training of MOs and Medical Technicians who were to operate hypobaric chambers, and of MOs who were to join the staff of the AMTC. Following a request by VCAS in 1972, newly appointed Station Commanders attended a one-day course designed to familiarise them with the work of the Institute. IAM also had valuable relationships with the Chief Test Pilots of the UK's aircraft and aero engine manufacturers. For many years these relationships were fostered by an annual meeting of test pilots at the Institute.

CONCLUSION

This account of some of the major efforts of the RAF Institute of Aviation Medicine from its formation in 1945 to 1994, when it became the RAF School of Aviation Medicine, records the success which the establishment had had in achieving the aim expressed in its motto *Ut secure volent* – 'That they may fly safely'. The Institute not only made major contributions to the safety of aircrew and passengers in flight but also, by research and designing and evaluating equipment, procedures and training, increased the efficiency and effectiveness with which military and civil aircrew performed their tasks.

DEVELOPMENT OF BREATHING SYSTEMS

CONTRIBUTIONS OF FLIGHT RESEARCH AND FLIGHT TRIALS

Dr Alistair J F Macmillan

Alistair Macmillan qualified in medicine (MB ChB) at Glasgow University in 1963. In 1965 he was commissioned into the Medical Branch of the RAF and joined the Altitude Division of the IAM. He left the Service in 1970 but remained with the Altitude Division, becoming its Head in 1980 and Deputy Director of Research (Personal Protection) in 1989. Promoted to Principal Medical Officer (Research) in 1991, a specialist in hypoxia, oxygen systems and partial pressure suits, Dr Macmillan is among this country's leading experts on decompression sickness and, although his experience is naturally centred on aviation, he has served as adviser on this topic to a number of outside bodies, including the Medical Research Council and British Standards Institution.

Introduction

Several well recognised phases are generally required in the development of breathing systems for aircrew. Initially, there is the definition of requirements which are determined by the operational role intended for the aircraft together with the physiological protection required for the aircrew in that operational environment. The necessary physiological protection is usually established by simulating the operational scenario in the laboratory and by assessments conducted in flight. Thereafter the specification for the equipment is generated.

In the later phases of development the performance of the equipment is assessed and measured, firstly in the laboratory and thereafter in flight. In the laboratory the environmental conditions of flight are simulated (eg altitude, acceleration, climatic conditions, etc) however the final test of a system or its components has to be in flight during which appropriate recording of the performance characteristics can be achieved.

After the equipment has proved to comply with its specification it is essential that acceptability to the users is then demonstrated in the appropriate role, by flight trials and service assessments by operational aircrew. These latter assessments confirm successful development and may also identify servicing requirements and cost of ownership.

Some of the most important contributions of flight assessments, both in research and during experimental or service trials, to the establishment of the functions of current breathing systems and in providing the supporting evidence for justifying the introduction of high quality user friendly equipment are reviewed in this paper.

Functions and Components of Breathing Systems

In present day high performance aircraft, breathing systems fulfil many functions. In addition to the historical provision of adequate oxygen pressure in the lungs, the system must: deliver the required respiratory flow and volume demands with minimum resistance; protect against acceleration lung collapse; enhance acceleration tolerance, by delivering positive pressure breathing; and protect the respiratory tract and eyes from chemical, biological and radioactive nuclear particles (CBRN). The components of modern systems comprise storage facilities, controlled delivery mechanisms and an acceptable interface with the user. Breathing gas may be stored as gaseous oxygen in high pressure cylinders, in vacuum containers as liquid oxygen or generated in flight by means of a molecular sieve oxygen concentrator. The interface with the user is achieved via an oro-nasal mask attached to the aircrew helmet and, since these two items are personal property, acceptability by the user is paramount.

Breathing System Functions

Maintenance of Adequate Oxygen Pressure in the Lungs

In 1783 Professor Charles and the Montgolfiere brothers had invented balloons capable of reaching high altitude, by means of hydrogen and hot air respectively, and the availability of these flying devices resulted in a period of ‘balloon mania’ during which it was quickly recognised that, although atmospheric pressure reduced with ascent, the composition of air remained constant. Throughout the nineteenth century many vivid reports of symptoms experienced during balloon flights were published, but it was not until the seminal experiments conducted by Paul Bert in France that the value of oxygen administration at altitude was demonstrated.

Aware of the physiological opinion of Paul Bert, three balloonists (Gaston Tissandier, Sivel and Croce-Spinelli) consulted him and duly experienced the effectiveness of oxygen in a simulated flight in his decompression chamber. With an oxygen and air mixture stored in skin bags one successful ascent in their balloon 'Zenith' was achieved in 1874 but the following year the second ascent met with disaster.

The balloon reached an estimated altitude of 28,000 feet, but all three, affected by cold and hypoxia, lost consciousness and only Tissandier survived. These first known fatalities occurred despite the preceding 'altitude' training in the decompression chamber and an oxygen supply available on board. Thus highlighting the need for robust oxygen storage facilities and a reliable means of administration.

Between 1918 and 1939 only rudimentary oxygen equipment was used in Royal Air Force aircraft. This comprised high pressure storage cylinders, hand controlled reducing valves with the oxygen delivered to the user via a pipe stem or valve-less mask. The cylinders were heavy, thus impacting on aircraft performance, and the delivery system, being continuous flow via a simple mouthpiece or mask, was wasteful and inefficient. At the outbreak of the Second World War the initial task of the newly established RAF Physiological Laboratory was to resolve the problem of providing oxygen for aircrew more efficiently and economically. The most serious deficiencies in existing equipment were quickly rectified by the development of the RAF economiser system which controlled the flow of oxygen into a flexible storage bag which emptied when the user inspired (Fig 1). This superior regulation of flow was accompanied by the development of an improved mask. The flow requirements were based initially on estimates of aircrew workload but subsequently, oxygen consumption and other respiratory variables were measured on aircrew in Stirling and Halifax bombers. However these measurements were conducted during experimental flights over the UK and it was not until 1943 that measurements were made by E A Goldie during a Lancaster bombing raid.

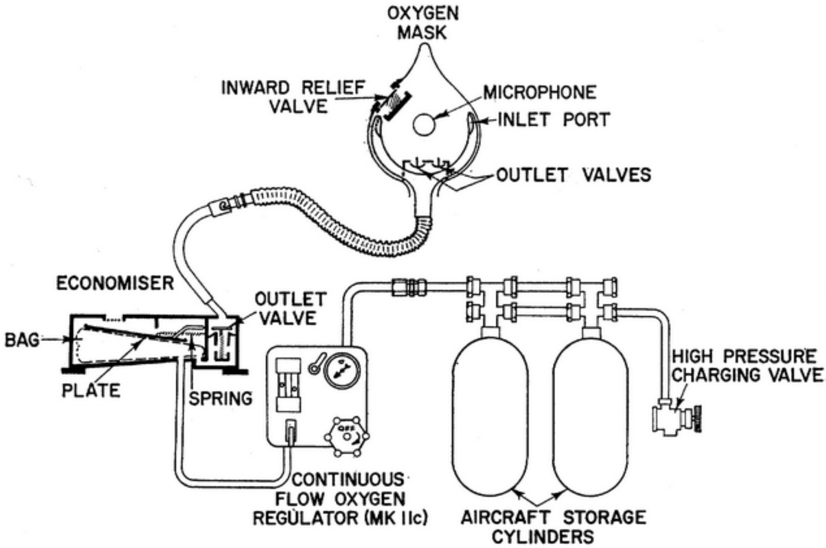


Fig 1 RAF Economiser system.

Goldie made control measurements during an experimental flight over the UK then measured respiration rates of the pilot and an observer throughout a 6½ hour operational bombing raid.

Not surprisingly, breathing rates recorded were considerably higher than the control measurements, particularly in the outward journey, and they were higher than any previously observed. These data clearly demonstrated that respiratory performance during operations might differ significantly from experimental flights. These differences could be due to the increased workload of manoeuvring, excitement or a combination of both, however the results confirmed that, in order to define adequately the physiological requirements for aircrew breathing systems, data obtained during realistic sorties are essential.

Meet Respiratory Flow and Volume Demands with Minimum Resistance

In the evolution of aircrew breathing systems between 1945 and 1970, emphasis was placed on the development of demand systems and the enhanced performance necessary for the delivery of positive pressure breathing for emergency exposures to altitudes above 40,000

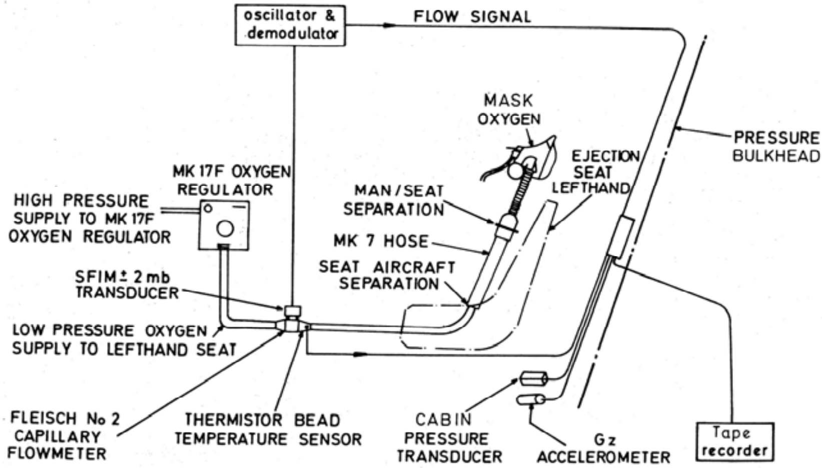


Fig 2. Hunter T Mk 7 Instrumentation for Respiratory Measurements.

feet. However, the flow requirements specified for these new demand systems were based on the physiological recommendations accepted in 1946. Nevertheless, recognising the desirability of low resistance to breathing, the UK led development of minimum resistance systems and formulated several standards which were adopted by other Nations. In 1976 measuring and recording facilities were sufficiently reduced in size and complexity to be easily installed in a high performance aircraft and the first respiratory measurements in aerobatic flight were conducted by the RAF Institute of Aviation Medicine (IAM) in the Institute's Hunter T7 (Fig 2).

These flights, comprising high +Gz spiral turns, loops and barrel rolls (Fig 3), identified that very high peak inspiratory flows were required in some manoeuvres and activities. Subsequent trials by squadron aircrew in Hawks refined the data, defined the high peak flows required (2.5% of breaths exceeded 200 litres per minute) and these results were incorporated in the design and performance criteria for subsequent oxygen systems.

Protection against Acceleration Lung Collapse

In 1949 two pilots participating in test flights, which involved exposure to much greater levels of applied acceleration than previously experienced, reported respiratory symptoms which were

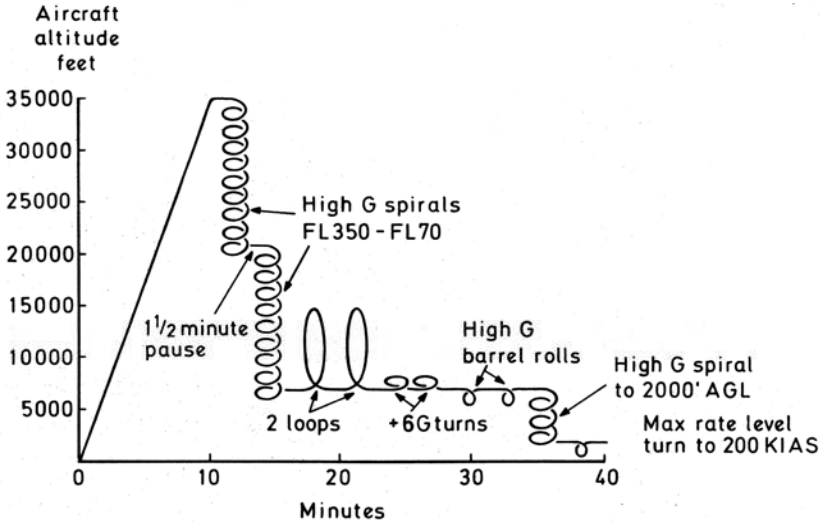


Fig 3. Schematic of sortie manoeuvres.

experienced at the completion of the sortie and resolved soon afterwards. These symptoms generally comprised: a dry, irritating, occasionally painful, cough; a desire to take a deep breath; and central chest pain on inspiration. Reports of these symptoms remained only sporadic however until the introduction of the Hawker Hunter and in the years 1955 to 1957, following its entry into service, numerous occurrences of respiratory symptoms were recorded. Consequently, in January 1957 a number of Hunter pilots underwent chest radiography immediately after completing a flight and the majority exhibited evidence of collapse at the bases of the lungs.

Between 1957 and 1959 a survey of aircrew from four aircraft types (Hunter, Javelin, Meteor and Canberra) revealed that there were three main factors which influenced the incidence of the condition. These factors were:

1) The level of applied acceleration.

2) Breathing 100% oxygen.

3) Wearing an anti-G suit.

Other possible contributory circumstances, such as duration of flight and altitude exposure, were not comparable within the surveys, neither could the degree to which each identified factor contributed to the respiratory symptoms be ascertained. Consequently it was decided to carry out a structured investigation designed to establish the role of these factors, obtain a better understanding of the disorder and enable procedures to mitigate or prevent the condition to be identified.

The trial took place at RAF Duxford during August 1960. Six experienced pilots participated and each had respiratory function tests and a chest X-ray performed before and immediately on completion of each sortie. Six combinations of gas mixtures (air mix or 100% oxygen) with three anti-G suit/applied G combinations were studied.

Chest X-rays and lung volume measurements confirmed that the combination of breathing 100% oxygen, wearing an anti-G suit and exposure to applied positive acceleration (+Gz) produced acceleration lung collapse. Subsequent laboratory experimentation at RAF IAM identified that limiting inspired oxygen concentration to 60% would prevent the lung collapse. This maximum oxygen concentration was therefore adopted for the breathing systems of high performance aircraft with intact cabin pressurisation when higher concentrations of oxygen to prevent hypoxia are not required.

Enhancement of +Gz Tolerance by Positive Pressure Breathing (PBG)

+Gz acceleration causes a fall in blood pressure at head level which, if sufficient, will result in loss of consciousness. Anti-G suits squeeze the limbs and abdomen, thus increasing the peripheral resistance, support the diaphragm and hence maintain the blood pressure. However, even the mechanical support provided by the anti-G system cannot completely prevent the fall in blood pressure and it is common practice for aircrew to perform an anti-G straining manoeuvre which, when properly performed, serves to raise the pressure in the chest which, in turn, is transmitted to the pressure within the heart and blood vessels. +Gz tolerance is therefore improved by this procedure. The manoeuvre requires conscious effort, is very fatiguing when performed frequently and, since the sole purpose is to raise the pressure in the chest, it was recognised that an identical result could be achieved by delivering breathing gas to the respiratory tract at pressures greater than ambient – a procedure well

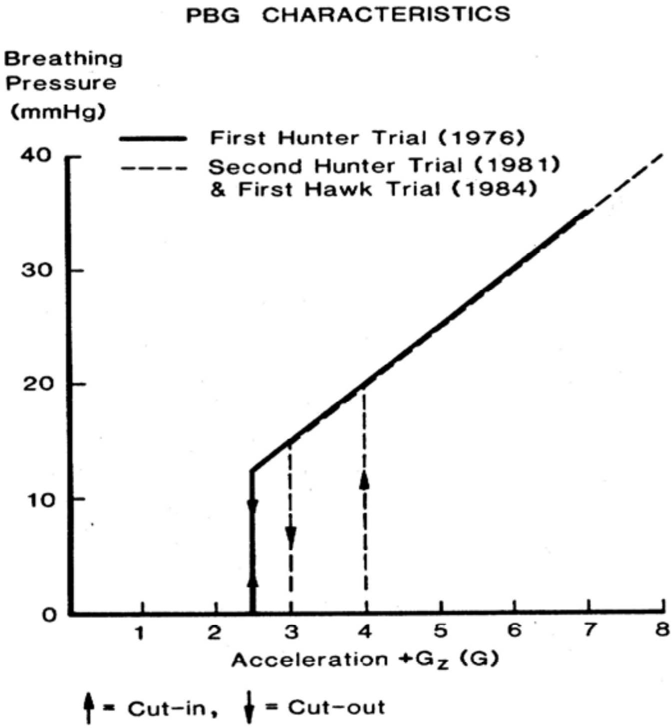


Fig 4.Characterstics of PBG.

established for protection at high altitude.

Experiments conducted in the RAF IAM man-carrying centrifuge between 1966 and 1975 confirmed that positive pressure breathing during exposure to +Gz was a potent enhancer of acceleration tolerance. It was therefore necessary to explore the possible benefits in flight. Consequently the world's first flight trials of PBG were conducted in the RAF IAM's research aircraft in the latter part of 1975 and early 1976.

These first PBG flight trials were conducted in a Hunter T7, utilising a modified Tornado regulator and a breathing gas mixture (60% oxygen; 40% nitrogen) to prevent lung collapse. The regulator modification provided PBG which commenced at +2.5Gz, increased linearly with increasing Gz to a maximum of 40 mm Hg and cut out when the +Gz level reduced to 2.5G (Fig 4). Seven pilots completed ten sorties, each reaching a maximum of +6Gz which was sustained for 30 seconds.

The pilots were enthusiastic about the PBG facility. It was deemed very acceptable in flight, considerably less fatiguing than the straining manoeuvre and was virtually ‘transparent’ to the subjects. However, the low level of acceleration at which PBG was activated was considered unacceptable and distracting during routine turns and low +Gz manoeuvres in the approach to landing and the pilots recommended that the cut-in level should be raised to 3-4G but that the cut out should remain between 2 and 3.

Additional flight trials were conducted during the 1980s, both in the IAM Hunter and by squadron aircrew at RAF Chivenor in Hawks. These trials confirmed the cut-in and cut-out levels recommended by the pilots in the earlier trials, established the acceptability of PBG in the higher acceleration envelope of the Hawk, and refined both the PBG schedule and protective garments. Thus were the enhanced +Gz protection facilities now in service in the Typhoon defined.

Protection of Respiratory Tract and Eyes from Chemical and Biological Agents and Radioactive Nuclear Particles (CBRN)

By 1972 attempts to develop an aircrew CBRN respirator which would integrate seamlessly with existing aircraft life support systems, and be acceptable to aircrew, had met with no success. Consequently the Research Establishments (RAF IAM and the Royal Aircraft Establishment (RAE)) were tasked to develop a suitable device. Three versions of respirators (identified as Aircrew Respirators NBC numbers AR2, AR3 and AR4) were developed between 1972 and 1975. Numbers 3 and 4 achieved pre-production standard and were intended for use in helicopters and fast jets respectively. However, neither integrated well with aircrew helmets or existing life support and weapon aiming systems, both were difficult to don and doff and were bulky and uncomfortable.

In April 1976 Mr R E Simpson, from the RAE, proposed a novel concept for an under-helmet respirator for helicopters which would integrate well with existing aircrew protective helmets and appropriate optical devices. It was quickly realised that this concept could be adapted readily for fast jets, albeit with some modification to the breathing gas supply systems in these aircraft. Thus was born the

Aircrew Respirator NBC Number 5 (AR5) and the critical phase of refinement and assessment to achieve aircrew and operational acceptability was commenced.

Since the AR5, with appropriate breathing gas supplies, was considered to be suitable for use in all aircraft types it had to be proved acceptable to all aircrew. Consequently the largest service evaluation of any new equipment ever done was undertaken by RAF IAM and RAE during 1978 and 1979. Aircrew from all fixed- and rotary-wing aircraft then in RAF service (eighteen types) participated in the trial. One hundred and twenty aircrew subjects, of whom 50% were pilots, completed a total of 140 dedicated aircraft sorties comprising 248 subject flights. Accumulated subject flight duration (varying from 30 minutes to 9 hours) amounted to 540 hours with individual wear times ranging from 1 hour to 13 hours 30 minutes.

On completion of the trials, 93% of the subjects considered the AR5 to be acceptable for operational use. Eight subjects rejected the assembly because of restriction of vision (air defence aircrew) or heat load and sweat in the eyes. Mitigation of these deficiencies was limited in the early days of operational use but the outstanding contributions of RAF IAM, RAE and the squadron pilots who supported the trials undoubtedly assured the unique achievement of successfully introducing the equipment into service in 1979 within 40 months of the initial concept.

This UK development was adopted by the US Navy in 1985 and still remains the most acceptable means of protecting the respiratory tract and eyes of aircrew from CBRN agents.

Components of Breathing Systems

Molecular Sieve Oxygen Concentrators

Until 1962 oxygen supplies in RAF aircraft were stored as gas in high pressure cylinders. Thereafter liquid oxygen (LOX) was adopted for future aircraft. However, LOX is difficult to handle, has serious logistic problems and is wasteful. During the early 1970s, research in the USA centred on the various chemical and physico/chemical processes which could be used to generate 100% oxygen on board aircraft thus eliminating the major disadvantages of LOX. All of the processes examined consumed large amounts of power which was not readily available on aircraft and were deemed unacceptable for on

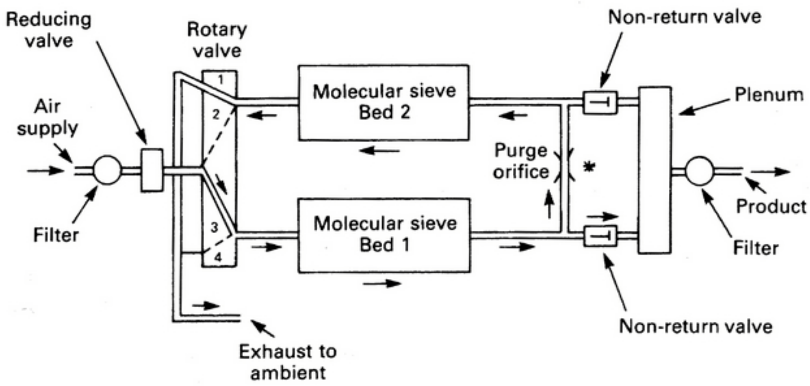


Fig 5. Schematic of a two-bed MSOC.

board use. However, some of these oxygen generating systems performed more efficiently if the concentration of oxygen in the gas to be processed was higher than that of air (>21%). Means of concentrating oxygen by low energy ‘filtration’ for this purpose were therefore studied and these investigations led to the development of efficient concentrating systems in which the oxygen content of the product gas could be controlled within physiologically acceptable limits.

In these molecular sieve oxygen concentrators (MSOC) pressurised conditioned air is delivered to the device and nitrogen in the air is trapped in a synthetic zeolite filtration material, thus allowing oxygen-rich breathing gas to flow through as the product. As the filtration bed becomes saturated with nitrogen it has to be regenerated by removing the trapped gas. This regeneration is achieved by reversing the flow of the air supply through the filtration bed thus purging the bed of the adsorbed nitrogen.

Accordingly, in order to achieve a constant flow of oxygen-rich gas, a minimum of two beds (one purging while the other produces oxygen-rich gas) is required (Fig 5).

In 1982 a UK manufacturer produced a three-bed system in which two beds were always ‘on line’, producing breathing gas, whilst the third was purging, thus avoiding the inevitable dip in oxygen concentration in two-bed systems which occurs as the direction of gas flow in the beds switches between them. The first flight assessments of this multi-bed system were conducted by RAF IAM later in1982. The trials, which comprised twenty-five sorties encompassing all phases of flight from taxying through high +Gz aerobatic manoeuvres and low level high speed flight, confirmed that the product gas was unaffected by the flight environment and the oxygen concentration was fully acceptable for all the conditions examined. The multi-bed system was subsequently adopted for the USAF's B-1B bomber and, in a modified form, for the Typhoon.

Masks and Helmets

With the development of positive pressure breathing facilities for protection against hypoxia at altitudes in excess of 40,000 feet it became necessary to ensure that leakage of gas at the interface with the user (the oxygen mask) was minimised or eliminated altogether. The mask in service in the early 1950s was the American A13A which could, in most individuals, seal at the positive pressures required, but it had to be worn so tightly to the face that it caused extreme discomfort. It was heartily disliked by aircrew, impaired downward vision and the large area of contact with the face caused irritation of the skin. Squadron Leader A B Goorney at RAF IAM was tasked with leading the development of a new mask and, although several iterations of designs were explored, it was not until 1959 that the P/Q series of oro-nasal oxygen masks were finally defined and introduced into service. Although the mask seal design was much more comfortable and effective than that of the A13A, it was the ingenuity of the design of the toggle suspension system, providing an easy means of tensioning the mask to the face when required, which ensured the success of the P/Q masks and both continue in service at the present time.

When the Tornado was entering development it was believed that, in order to prevent head and face injury, following ejection at very high speeds (600 knots), it would be necessary to wear a helmet which totally enclosed the head and face. Consequently the oxygen mask had to be integrated into the helmet and this was achieved by mounting the mask on the chin bar of the head-enclosing helmet. This helmet, designated the High Speed Anti-Blast (or Buffet) or Type 5, helmet was assessed in flight trials by aircrew on Buccaneers, Phantoms, Lightnings and Harriers during 1972. Seventeen aircrew completed

148 sorties and were almost unanimous in condemning the helmet as unacceptable.

The aircrew identified many minor faults; including the chin bar closure mechanism and the means of operating the single visor. In addition, the design exhibited major user problems, including restriction of downward vision, impairment of head mobility and, with total head enclosure, was unacceptably hot. Thus, although performing satisfactorily in the laboratory, and proving capable of protecting the face eyes and head at 600 knots, the assessments in flight by operational aircrew clearly demonstrated its unsuitability for the role intended and the development was abandoned.

Conclusions/Lessons from History

The foregoing paragraphs have provided a mere glimpse at the contribution of flight trials and flight research in the development of reliable and 'user friendly' breathing systems for aircrew. Nevertheless, lessons contained in the investigations outlined are indisputable.

1) Flight Research and Flight Trials have been cornerstones in the development of RAF breathing systems.
2) Generation of robust evidence from flight trials requires:
    a) Representative aircraft.
    b) Flight worthy experimental/prototype equipment.
    c) Appropriate instrumentation, calibration and recording facilities.
    d) Realistic flight profiles.
    e) In the research phases, subjects experienced in research flying.
    f) Service assessments by operational squadron aircrew.
    g) Properly designed questionnaires or structured debriefing.

Comprehensive flight assessments must continue to underpin all developments and improvements to life support systems and aircrew equipment in order to ensure satisfactory performance, user acceptability and avoid major problems in service.

THE FIGHT AGAINST G

by Wg Cdr N D C Green

Nic Green joined the RAF in 1990 and during his initial tour at St Mawgan he gained practical experience of aeromedical evacuation during the first Gulf War. He spent 1992-97 at the Institute of Aviation Medicine where he worked on long-duration acceleration using the human centrifuge and assisted in the development of the anti-G system for the Typhoon. With the closure of IAM, he returned to hospital medicine until 2001, when he was posted to the Centre of Aviation Medicine at Henlow, where he is presently Officer Commanding Aviation Physiology Section. He was recently appointed as a Defence Medical Services Consultant in Aviation Medicine.

Introduction

This review focuses on the pioneering British work conducted in the fight against G. It should be noted that a considerable amount of experimental work on this topic was also conducted in the United States, which is not described in detail herein. The problems associated with G exposure, and the risk of G-induced loss of consciousness (from an inadequate supply of blood to the head at high G) remains pertinent to aircrew even today.

Early years

The problems that exposure to high G force might bring were apparent within a few short years of the Wright brothers' first flight. In 1918, Professor Henry Head reported to the Medical Research Council on the results of test flights conducted in a Sopwith Triplane.[1] A test pilot, flying a 4.5G banked turn, experienced 'characteristic darkening of the sky which was preliminary to fainting'. At that time, the cause of these observations was not understood and there was no attempt to protect pilots against the effects. Indeed, the earliest recorded episode of G-induced loss of consciousness (G-LOC) occurred in 1903 during testing of Sir Hiram Maxim's Captive Flying Machine, when Dr (later Professor) A P Thurston lost consciousness at +6.87Gz. Professor Thurston later established the first formal UK teaching course in aeronautics at East London College in 1907.

In the RAF, it was not until the Schneider Trophy Races of the 1920s that a concerted effort was made to protect pilots against the effects of G exposure. Following a victory in 1922, subsequent poor performance of the British team resulted in the RAF being given full responsibility for the effort in 1927. Many hours were spent practising high speed flight, including tight turns around the course pylons, during which greyout and blackout of vision were encountered. Group Captain Flack, who was Officer Commanding the Central Medical Establishment and Director of Medical Research at the time, was asked for advice. He devised an elastic abdominal belt, which was intended to stop blood pooling in the abdomen under G. Unfortunately, the belt was not well liked by the pilots, who found that it was uncomfortable and slipped down under G, restricting movement in the cockpit. The Schneider pilots found that muscle tensing (particularly of the abdomen) was a better way to preserve vision. Later, the team changed tactics to corner at lower G (around +5Gz) which resulted in less vital speed being lost,[2] and so it was decided that the belt was not necessary. The team went on to win the Trophy in the Supermarine S5 in 1927, and then again in 1929 in the S6, and for a final time in 1931 in the S6b, which won Britain the Trophy in perpetuity. The abdominal belt was also investigated in the US in 1932 by Captain Poppen,[3] in an attempt to improve G protection in US Navy aircraft. This belt was as unsuccessful as its British counterpart, but its development still formed part of the central story in the 1941 Hollywood movie *Dive Bomber* which starred Errol Flynn as a young US Navy flight surgeon.

The coming of war

Little RAF work was conducted on the problems of high G flying in the years preceding World War II, as the Air Staff believed that the speed of modern aircraft would make dogfights outdated. In 1937, following a visit by Wg Cdr Philip Livingston to German aviation medicine research facilities, the poor state of Britain's preparedness and lack of expertise in aviation medicine was identified.[4] On 7 June 1939, at a meeting of the newly formed Flying Personnel Research Committee, it was agreed that experimental work on G protection was urgently required, and this was initially led by Gp Capt Struan

Fg Off (later AVM) Bill Stewart in the Battle.

Marshall. Plans were made for the installation of a human centrifuge at Farnborough for research purposes, but the Air Staff remained unconvinced about its importance, and the centrifuge was dismissed as being far too expensive (at a cost of some £7,500). It was decided that studies would be conducted in aircraft instead, but, as it turned out, the cost of research flights far exceeded that of a centrifuge, with around 175 flights being made between 1940 and 1941 alone. The lack of a UK centrifuge meant that the RAF became increasingly dependent upon the Canadians, Americans and Australians for the development of anti-G suits: all these nations had built centrifuges immediately before or during the war.

Wartime flight research into G

Despite the absence of a centrifuge, the newly formed RAF Physiological Laboratory at Farnborough conducted an active programme of research into methods of protection against the problems of 'blackout' in flight. The unit was initially supplied with a Harvard for the purpose, but this aircraft was found to be wholly unsuitable for sustained G work and was quickly withdrawn. A Gloster Gladiator and a Fairey Battle were later supplied and these became the mainstay of G research. The aircraft were modified with a specially mounted camera that could record a G meter and the subject's reactions to acceleration. Flight research into acceleration was supervised by Fg Off (later AVM) Bill Stewart, who, together with Sqn Ldr G E Watt, conducted pioneering acceleration work throughout the early days of World War II. Often a subject of his own experiments, Stewart was to black out over 200 times before the war was over, providing graphic evidence of the effects. His studies provided findings that supported work from the United States on the physiological basis of blackout and G-LOC, and also resulted in practical advice to front line aircrew at the time.

It was found that by adopting a crouching posture, G tolerance could be increased by at least +1Gz.[5] A film made by Stewart and Watt was circulated around Fighter Command to provide valuable education in G counter-measures, including the crouching manoeuvre,[6] and using these techniques, Wg Cdr Stainforth and Sqn Ldr Watt found themselves able to reach the structural limit of the Gladiator (+7.5Gz) without blacking out. Research into the effectiveness of the 'Cadzow' abdominal belt found the device to be entirely ineffective.[7] It was proposed by Sqn Ldr Watt that for maximum effectiveness in air combat, fighter aircraft should be fitted with a G meter.[8] It was known that a Spitfire or Hurricane would break up at +12Gz, and sustain damage above +9Gz. However, Watt felt that pilots who could confidently pull +8Gz without fear of over-stressing the aircraft would have a clear advantage in battle. He designed a device specifically for the task, the 'Watt accelerometer', which was used with success in Defiant aircraft at Dunkirk.[9]

Trials supervised by Stewart found that, when flying against a Messerschmitt 109 flown by Wg Cdr Stainforth, G tolerance could be much improved by elevating the position of the legs by 6 inches (to reduced pooling of blood).[9] Auxiliary rudder pedals were later fitted to the existing rudder bars of Hurricanes and Spitfires such that the legs could be raised in combat. An investigation by Stewart into the possibility of reclining the pilot in his seat to improve G tolerance demonstrated that pilots were able to tolerate +6Gz for 9 seconds with a seat set back at 45°.[10] This idea was not taken forward at that time, but was investigated again in the 1950s. A thorough evaluation of abdominal belts demonstrated once and for all that they were of no practical use,[11] and attention was turned to experimentation with crude water-filled leggings. Whilst an elevation in blackout threshold of around +0.5Gz was achieved, this work was soon discontinued when the first true anti-G suit, designed by Wilbur Franks in Canada, became available for testing.

The first anti-G suits

The Franks Flying Suit was developed in 1940 and consisted of non-stretch water filled bladders over the abdomen and lower extremities, which provided counter-pressure against the effects of G force on the blood. Limited funding was available in Canada for testing, and Franks (by then a flight lieutenant in the Royal Canadian

The Franks water-filled anti-G suit.

Air Force) came over to the Physiological Laboratory at Farnborough to supervise flight testing of the suit. One of the greatest problems was in achieving a close fit of the outer restraining layer over each individual, which effectively necessitated a personal custom-tailored garment. Mobility in the suit was poor, and the suits were hot to wear and caused profuse sweating. Acceleration protection was good, however, with the blackout threshold raised as much as +3Gz.[12]

Manufacture of the Mk 1 Franks Flying Suit by the Dunlop Rubber Company proceeded with just three sizes, which was soon found to be a fundamental flaw: the critical importance of tight fit was lost, and the suit was ineffective. As a result, the Mk 1 suit never entered service and all garments were destroyed! Modifications were made to improve the fit of the suit, and a Mk 3 suit was devised, but there remained problems with a loss of sensation when flying the aircraft due to the water-filled lining. Over 8,000 suits appear to have been manufactured, but very few were used in operational aircraft. In fact, the suit never officially entered service. The complexity, bulk and cumbersome water filling requirements on the ground were off-putting, and RAF Fighter Command feared that use of the suits might tempt pilots to exceed the structural limits of their aircraft. The Fleet Air Arm was more enthusiastic, and used 150 suits during the North Africa Campaign. However, obsessive secrecy about the suit resulted in its use being forbidden over enemy territory, which at that stage of the war made it almost redundant.[4] The final blow for the water-filled suit came with the emergence of simpler, cheaper, air filled anti-G suits which were just as effective.

The RAF Physiological Laboratory also evaluated the first air

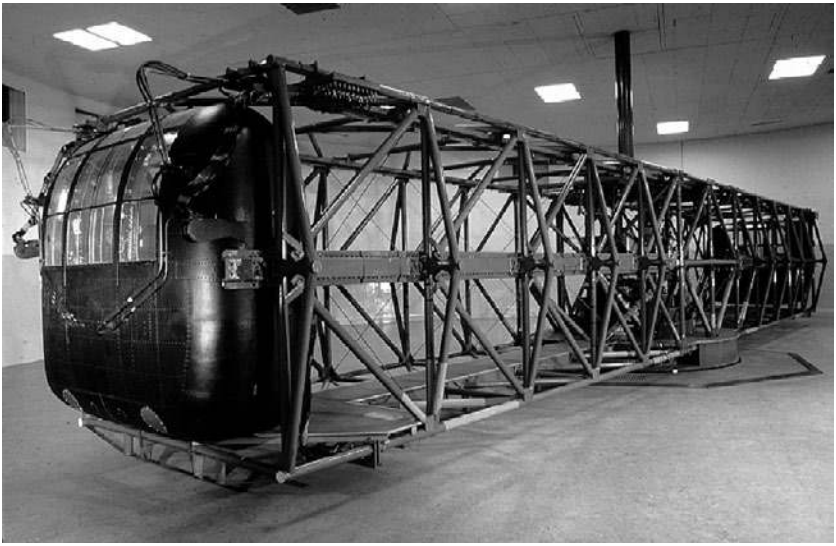
The Australian Cotton suit (left) and the American G2 suit (right) were both air-filled.

filled G suit developed by Professor Frank Cotton in Australia.[13] Like the Franks suit, the Cotton Suit was heavy, cumbersome and uncomfortable due to the use of graded pressures in the various inflatable bladders of the garment. However, Cotton received only limited support from the RAF, which was pursuing the water-filled option. The suit was well supported in Australia and was used in limited numbers by Spitfire pilots flying from Darwin in 1943. Like the Franks suit, the Cotton suit saw little air combat, as pilots had been instructed not to dogfight in their ageing Spitfires against superior Japanese aircraft.[14]

Without doubt, however, the real story of the air-filled G suit is essentially American. Following Pearl Harbour, an aggressive research programme was pursued which involved initial evaluation of the Franks Flying Suit and the Cotton Suit on the centrifuge and in flight. Deficiencies were noted and corrected, resulting in a suit which had a single pressure throughout the garment. The Spencer-Berger Single Pressure Suit G1, so developed, was comfortable and raised G tolerance by about +1Gz, by the use of four thigh and four calf bladders in a full coverall. It was quickly appreciated, both at Farnborough[15] and in the United States, that a skeletal version of the suit with five single bladders (the G2) provided adequate protection and had far fewer thermal problems than the full coverage garment. Despite the development of this suit, and the extensive research and testing programmes carried out at Farnborough, no anti-G suit saw operational service with the RAF until after the war ended.

The post-war years

Some G-related flight research continued after World War II in a Spitfire Mk 9 (later written off by Wg Cdr Ruffell-Smith), a Spitfire Mk 21 and Meteors and Vampires until the Farnborough centrifuge came into service. However, anti-G suits were only used on an ad hoc basis by the RAF until the introduction of the Hawker Hunter in 1954. These suits, manufactured by the Dunlop Rubber Company, were essentially copies of American skeletal garments. Studies continued in the United States with different technologies, including the arterial occlusion suit which, although highly effective in improving G tolerance (by cutting off the blood supply to the legs), caused severe pain. The RAF Institute of Aviation Medicine (IAM) at Farnborough, formed from the Physiological Laboratory, finally acquired its human centrifuge in 1955. The machine was first used for work conducted on the physiological basis of blackout, by Sqn Ldr (later AVM) Peter Howard. Over the following years, refinements were made to RAF anti-G trousers, all based on the five-bladder wartime design. Collaboration between IAM and Dunlop Special Products resulted in the Mk 4 anti-G suit, with improved mobility and comfort.[16] In the 1960s, the Mks 6 and 7 anti-G suits were developed in co-operation



The IAM finally acquired a centrifuge in 1955.

with the Frankenstein Company, which were better suited for use in hot climates. The G level at which the suits started to inflate and their inflation pressures (supplied by an anti-G valve) were the subjects of intensive research. Materials changed from heavy rubber to lightweight synthetic compounds, and in the 1970s, external anti-G trousers were developed to be worn outside the flying coverall.

Others solutions to the G problem

In the 1950s, flight research was carried out into the possibility of using a prone body position to protect pilots against the effects of G force. Believing that fast jets would require a very low frontal profile to reduce airframe drag, the Ministry of Supply bought the Reid and Sigrist RS3 Desford for research purposes in 1948. The aircraft was originally constructed as a twin-engined trainer, and only a single airframe was ever made. In order to adapt it for prone pilot studies, the nose of the aircraft was lengthened and glazed, and a prone pilot station was installed in the new nose. In addition to the main transparent nose-cone, two separate transparent ports gave limited sideways and rearwards views. The original cockpit of the aircraft was also retained. Marking the change in pilot position, the aircraft was re-

Above – the Reid and Sigrist RS3 Desford, seen here after conversion to become the prone-pilot RS4 Bobsleigh, which was used for trials work from 1951, supplemented from 1954 by a modified Meteor (below).

designated the RS4 Bobsleigh, and was first flown (as VZ728) on 13 June 1951. Aeromedical research flights, including some flown by Wg Cdr Ruffell-Smith, found that the instruments were (initially) too close-up to see clearly. The prone position also caused neck ache, and the aircraft was almost unflyable in heavy turbulence.

Research continued later on a specially adapted Meteor 8, WK935, which first flew on 10 February 1954 with the IAM. Again, the initial driver for this research was airframe design rather than a quest to improve G protection. The aircraft was modified to take a pilot lying down in the forward fuselage, and had a conventional rear cockpit for a 'safety pilot'. Trials carried out in 1954-55 involved 99 sorties and demonstrated exceptionally good G protection. However, unacceptable difficulties arose in exterior visibility, comfort (especially at low level during turbulence) and in control of the aircraft. Latterly, the aircraft was retired to the RAF Museum at Cosford.

A taste of the future

In the search to offer improved G protection to the pilots of future highly agile aircraft, investigations into positive pressure breathing for G protection began in the 1970s. After promising results on the Farnborough centrifuge, flight trials conducted at the Tactical Weapons Unit at RAF Brawdy in 1984 indicated that pressure breathing could make an important contribution to enhanced G protection.[17] Later development of the system by industry, in concert with IAM, resulted in the advanced anti-G system which is now fitted to the Typhoon.

From its earliest days of in-flight research, to later centrifuge programmes, the legacy provided by British pioneers in acceleration research throughout the 20th Century has enabled the UK to field world leading anti-G technology in its aircraft of the 21st Century.

References:

[1] Head, H; 'The sense and stability of balance in the air.' Medical Research Council Report into The Medical Problems of Flying (London, His Majesty's Stationery Office, 1920) pp214-256.

[2] Schofield, H M; *The High Speed and other flights*. London (John Hamilton Limited, 1932).

[3] Poppen, J R and Drinker, C K; 'Physiological effects and possible methods of

reducing the symptoms produced by rapid changes in the speed and direction of airplanes as measured in actual flight', Journal of Applied Physiology, 1950, Vol 3, pp204-215.
[4] Harrison, M H and Gibson T M; *Into Thin Air* (London, Robert Hale Ltd, 1984).
[5] Stewart, W K; 'Progress report: oxygen separator; pressure cabins; 'Puffing Billy' masks and economiser; education; bends; acceleration; frostbite', CO Flying Personnel Research Committee Report No 111, Air Ministry, London, 1940.
[6] Stewart, W K; 'Report on acceleration', Flying Personnel Research Committee Report No 136a, Air Ministry, London, 1940.
[7] Stewart, W K; 'Report on acceleration', Flying Personnel Research Committee Report No 112, Air Ministry, London, 1940.
[8] Watt, G E; 'Centrifugal acceleration in aircraft as it affects the fighter pilot', Flying Personnel Research Committee Report No 136b, Air Ministry, London, 1940.
[9] Watt, G E; 'Progress report: oxygen separator; CO lectures; drugs; bends; respiration at high altitude; acceleration film; accelerometers', Flying Personnel Research Committee Report No 159, Air Ministry, London, 1940.
[10] Stewart, W K; 'Effect of reclining posture on ability to withstand high G', Flying Personnel Research Committee Report No 212, Air Ministry, London, 1940.
[11] Stewart, W K; 'Efficiency of abdominal belts in the prevention of blacking-out', Flying Personnel Committee Report No 176, Air Ministry, London, 1940.
[12] Franks, W R; 'Test flights with hydrostatic suit', Flying Personnel Research Committee Report No 301, Air Ministry, London, 1941.
[13] Stewart, W K; 'Report on Professor F C Cotton's pneumodynamic suit', Flying Personnel Research Committee Report No 407, Air Ministry, London, 1942.
[14] Harrison, M H and Gibson, T M; 'British Aviation Medicine during the Second World War, Part 2: G-Protection', IAM Report No 610, Ministry of Defence, London, 1981.
[15] Stewart, W K; 'Note on Spencer acceleration belt and leggings USA firm', Flying Personnel Research Committee Report No 458, Air Ministry, London, 1942.
[16] Harrison, M H and Gibson, T M; 'The history of the IAM: acceleration research since 1945', IAM Report No 618, Ministry of Defence, London, 1982.
[17] Bagshaw, M A; 'Flight Trial of Positive Pressure Breathing During Acceleration Using RAF Hawk Aircraft at a Tactical Weapons Unit', IAM Report No R637, Ministry of Defence, London, 1984.

A SHORT HISTORY OF AEROMEDICAL EVACUATION

by Wg Cdr M J Ruth

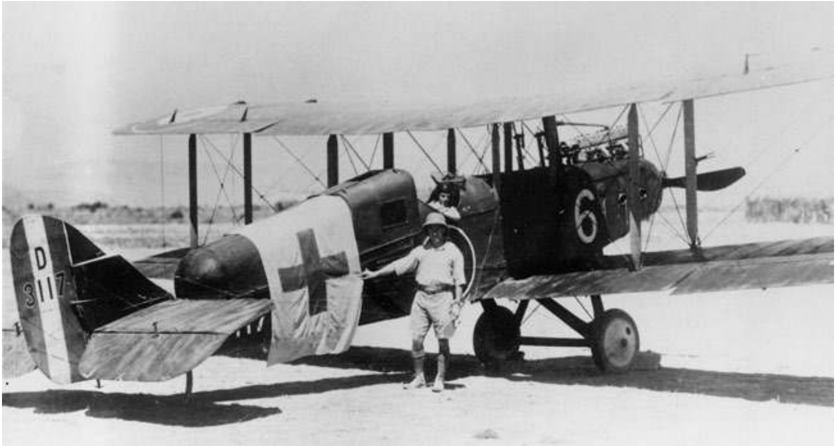
Martin Ruth joined the RAF in 1991. After a stint at Lossiemouth he served at RAF Hospitals Wegberg, Halton and Wroughton. Specialising in anaesthesia since 1993, he has been based primarily on the Edinburgh Infirmary since 1995, dividing his time between the NHS and the RAF, including a year in Australia and periods spent in Kosovo, Iraq and Afghanistan. His current appointment as a Critical Care Air Support Team Medical Officer involves being on-call to fly out to Afghanistan to oversee the evacuation of wounded personnel in the field, their subsequent transfers between medical facilities in-theatre and their eventual repatriation to the UK.

Beginnings

The first use of air transport as a means to move patients is often stated to have occurred in 1870 during the siege of Paris in the Franco-Prussian War. Many texts quote Dr H G Armstrong's 1952 book on aviation medicine which claims that 160 patients were removed from the city by means of observation balloons.[1&2] This would have been an appropriate, indeed the only, method of evacuating the sick safely to outside aid. Unfortunately this has been shown to be untrue. Although it would have been possible for the balloons to perform this function, an examination of 167 actual documented flights between September 1870 and January 1871 has indicated that none carried any sick or wounded.[3] Their main task was to maintain communications with the provisional seat of government in Tours and sixty were actually contracted and paid for by the postal service.

The idea of moving patients by air was actually proposed in 1910 when Dr De-Mooy, a Dutch military physician, suggested a system of Red Cross 'Zeppelin' type balloons to remove wounded men from the battlefield. This is where the use of aircraft came into its own.

The next mention, in research, of the use of aircraft again comes in Dr Armstrong's book when, in 1909, a Capt George Gosman and Lt A L Rhodes of the US Army tried, but failed, to build a patient-carrying



Well- known picture of one of the DH 9s modified for use as an air ambulances during the Somaliland expedition of 1919.

aircraft. There is little or no explanation in the literature as to why this was being attempted. There seems to have been no specific need for it, beyond the fact that 'it could be done, therefore it was done'. Nevertheless, it was a logical step forward and in 1915, spurred on by the needs of war wounded, the first documented case of aeromedical evacuation (AE) was carried out by the French who evacuated a Serbian (or Albanian – sources differ) in an unmodified fighter. At this time the French very much led the way, principally because there was a great need for this in Morocco and the Levant.

The first British record of a wounded man being moved by air was very much an *ad hoc* arrangement when a trooper, from the Imperial Camel Corps, who had been shot in the ankle by a Bedouin, was placed in the observer's seat of a DH 4.[4] This flight took 45 minutes, as opposed to the journey overland that would have taken three days.

In an article by Air Commodore Glynn, he states that in 1919 the first specifically designed air ambulances were authorised for the RAF and first used in the autumn of that year on the 'Z' expedition.[5] The air commodore describes it as follows:

> '...a 'punitive' expedition of 214 all ranks that went out to Somaliland in the autumn of 1919 to settle the account of that, then hardy annual, the 'Mad Mullah'…'

Development

The air ambulance used in Somaliland was a DH 9 modified to carry a stretcher and attendant, and though an experiment, it quickly proved its worth. The fuselage opened, coffin-style, to allow the patient complete coverage with the attendant standing fore of the patient with his back to the pilot. This had the advantage of protecting the patient from exposure but did not facilitate much doctor-patient contact, physical or verbal. The first case for which it was used involved another Camel Corps soldier, this time one with a septic toe, who was flown 75 miles to an advanced hospital. This journey would normally have taken three days and the patient would almost certainly have died on the way.

Ongoing treatment in-flight was not really feasible until the French took up the long distance challenge in their colonies in the 1920s using a derivative of the wartime Breguet 14A2 and B2 reconnaissance and day bombers known as the Breguet 14S (S for s*anitaire*) and able to accommodate two stretcher cases and a medical officer.

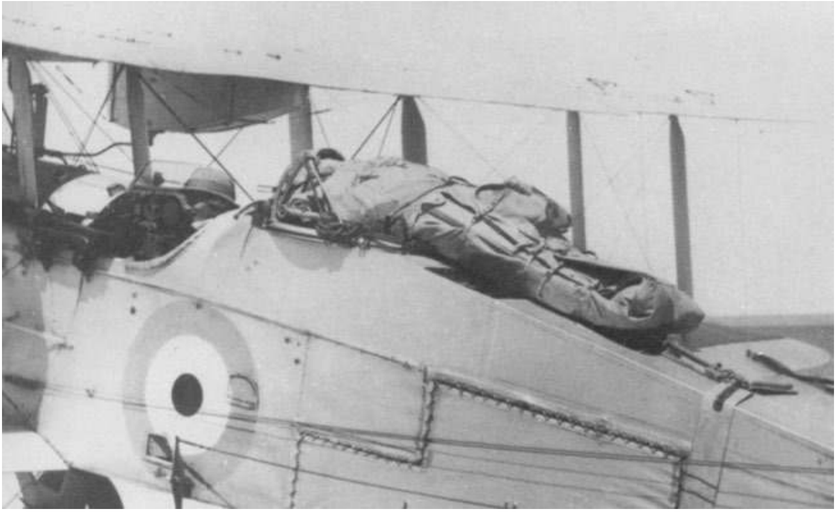
This was a huge leap forward with electrically heated warming bags, oxygen, first-aid equipment, bedpans and urine bottles. The last two items were mounted in holes in the fuselage so that they directly emptied in flight which, even at that early date, was noted as being a serious health hazard.[6] A major limitation of the Breguet was its lack of wireless but the French were heavily committed to the ambulance concept and in 1926 they had ninety-five of them on charge, mostly for use in colonial campaigns.

The RAF was not to be outdone and in 1921 a state-of-the-art Vickers Vernon ambulance was produced at Weybridge. This aircraft had a detachable nose-door that allowed patient loading directly into the body of the aircraft. The stretchers would run along special grooves up to collapsible stretcher racks. It could take four patients, a medical officer, a fitter, a wireless operator and the two pilots. Not only did it have a wireless but it also had a washbasin, fan, electric kettle, 40 gallons of drinking water and a drug cupboard – and the toilet collected its waste, rather than depositing it over a wide area below. Alas, after much time and effort spent on alterations it crashed, shortly after appearing in Aboukir in 1922. Four production Vernon Ambulances followed and these saw extensive use between 1922 and

Above, a Vernon Ambulance, J7143, of No 45 Sqn and. (left) its interior.

1925, often plying between Baghdad and Kirkuk. The aircraft were considered to be comfortable but draughty, following (as a weight saving measure) the substitution of gauze windows for the original triplex glass

The first major demonstration of the pot-ential of casualty evacuation by air came in April 1923 when 198 patients, suffering from diarrhoea and dysentery, were airlifted from Northern Kurdistan to Baghdad.[5] This operation took four days and involved twelve Vernons mounting 95 sorties for a total of 128 hours and 45 minutes of flying time. The evacuation was marred by bad weather but, despite the extremely ‘bumpy’ conditions, some of the passengers were said to have enjoyed the experience (of what was probably their first flight). During this operation one of the aircraft failed to clear the Adghir Dagh ridge and crash landed. Fortunately, no one was hurt but the site was virtually inaccessible by air, although, through a remarkable display of skill, a Bristol Fighter carrying a Medical Officer did manage to land. The most seriously ill patient was



A 'casualty' strapped securely into a Neil Robertson stretcher protected by a canvas cover and lashed to the Scarff ring and fuselage decking of a DH 9A.

flown out in the Bristol, the MO remaining with the stranded party who were eventually brought out on foot and/or by mule. (*See page 122)*

Had the unsatisfactory nature of the site not made its use impractical, it might have been possible to employ another facility that had been developed in-theatre. This involved strapping the patient into a Neil Robertson stretcher within a one-piece cover made of Willesden green canvas lined with blanketing, the whole affair being lashed to the decking of a DH 9A or Bristol Fighter.

The common theme in all these incidents was the need to get patients from inhospitable areas back to be treated. Today we fly seriously ill patients to gain access to advanced surgical techniques and diagnostics which both rely heavily on technology. In the 1920s patients were being moved simply to get treatment. The Vernon was especially suited to the evacuation of patients from Iraq to Egypt. Even with a night stop this took two days as compared with three to four weeks, via Basra and Bombay. Furthermore, the sea crossing could be unbearably hot in the summer and rough during the Monsoon season. The Vernon's superiority over other forms of patient transport

Year	Numbers	Chief Locality
1919	3	Somaliland operations.
1920	0	Development of air ambulance.
1921	0	Development of air ambulance.
1922	0	Development of air ambulance.
1923	359	Iraq – 198 mass evacuation
1924	81	Iraq.
1925	176	Iraq.
1926	130	Iraq.
1927	125	Iraq and Palestine.
1928	86	Iraq and Palestine.
1929	66	Iraq and Palestine.
1930	91	Iraq.
1931	125	104 in Iraq.
1932	177	138 in Iraq.
1933	188	159 in Iraq.
1934	173	Iraq.
1935	418	Iraq and India (Quetta earthquake).
1936	161	Iraq.
1937	298	157 in Waziristan; 89 in Iraq.
1938	149	70 in Iraq; 47 in Palestine; 22 in India; 10 in other commands.

Fig 1. RAF Air Ambulance activity 1919-38.

had led to the acquisition of its successor, the Avro Andover.

The Andover had greater headroom, efficient hot and cold ventilation, good-sized lockers, seven hour's worth of fuel and, most importantly (even in those days), it was much cheaper to run. But, the April 1923 airlift in Iraq had been carried out by ordinary Vernons, not the specialised ambulance variants, and, since transport aircraft could evidently do the job, it was concluded that it was an unnecessary complication (and expense) to procure dedicated ambulances. In June 1925 the two Andovers that were built were assigned to ferry patients to the RAF Hospital at Halton, but *only* when this would be quicker than moving them to the nearest hospital by other means. Since England was so amply provided with road and rail links, the Andovers carried only three patients in four months and the enterprise was abandoned in mid-December. Nevertheless, although it no longer operated an air ambulance service *per se*, as Figure 1 indicates, between 1919 and 1938 the RAF carried around 2,800 casualties, mostly in the Middle East, and some interest in air ambulances remained within the Air Ministry who gave approval in 1933 to a British Red Cross scheme to form civilian air ambulance detachments. Unfortunately, this never got off the ground. The *Luftwaffe*, meanwhile, was quickly gaining experience and investing in mass-casualty transfer by air.

The *Luftwaffe*

From it's founding in 1935 the *Luftwaffe*'s first Surgeon General, Erich Hippke, was interested in the concept of AE and the Spanish Civil War provided an ideal opportunity to gain practical experience. The journey from Spain to Berlin was around 1,500 miles and took 10 hours and occasionally involved flying at altitudes of up to 18,000 feet, which, since the aircraft used, Ju 52s, were unpressurised, required supplemental oxygen. Despite conveying what appear to have been severely ill patients, there were no adverse incidents.[7]

The Ju 52s of the Condor Legion had actually been bombers, adapted to carry four stretchers, two tiers of two, along each side. By the time that WW II broke out, however, the Ju 52 had been relegated to transport duties. Air transport was, of course, ideally suited to rapidly moving *Blitzkreig* operations and when Germany invaded Poland 1,250 casualties were evacuated by air within four weeks. From 1941 onwards new production Ju 52s were being built with large doors on the starboard side, which considerably eased the loading and unloading of patients when operating in the ambulance role.

In that same year a number of dedicated AE units (*Sanitäts-Flugbereitschaft*) was formed. The establishment of airlift facilities on this scale was remarkable in itself but what was equally notable was that it permitted the provision of specialist care in-flight. The neurosurgeon, Wilhem Toennis, for instance, escorted 557 patients with chest, abdominal and head wounds. A few died but many survived, because they were given intravenous fluids, actively rewarmed in flight after surgical procedures and given blood if it was required. The only patients who were refused AE were those in shock or in danger of collapse. This is no different from today.

By 1942 a typical German air ambulance unit had 140 personnel, five Ju 52s and a couple of Fi 156 STOL aeroplanes which could be used for recovering single casualties from landing strips near the front and conveying them to more sophisticated facilities. They were so successful that the German press of the time reported that they had flown 280,000 casualties from the Russian front back to Germany, although it is possible that this figure may have been exaggerated for effect.

It goes without saying that transporting casualties, or anything else, by air required air superiority. Without it the aircraft risked being shot down. In an effort to prevent this, Articles 18 and 19 of the Geneva Convention of 1929 state that aircraft used *solely* for AE should be painted white and display 'Red Cross' markings. It didn't take long for them to become camouflaged in the usual way, however, since all-white aeroplanes were easily spotted from the air, thus revealing the location of forward airfields. The Germans did retain red crosses within white circles to distinguish them from normal transports but this was hardly sufficient to identify them as mercy flights. Eventually, in 1943, the Germans removed all identifying insignia from their air ambulances because they felt they were being specifically targeted, especially in the Mediterranean theatre.[7]

World War II and the Western Desert

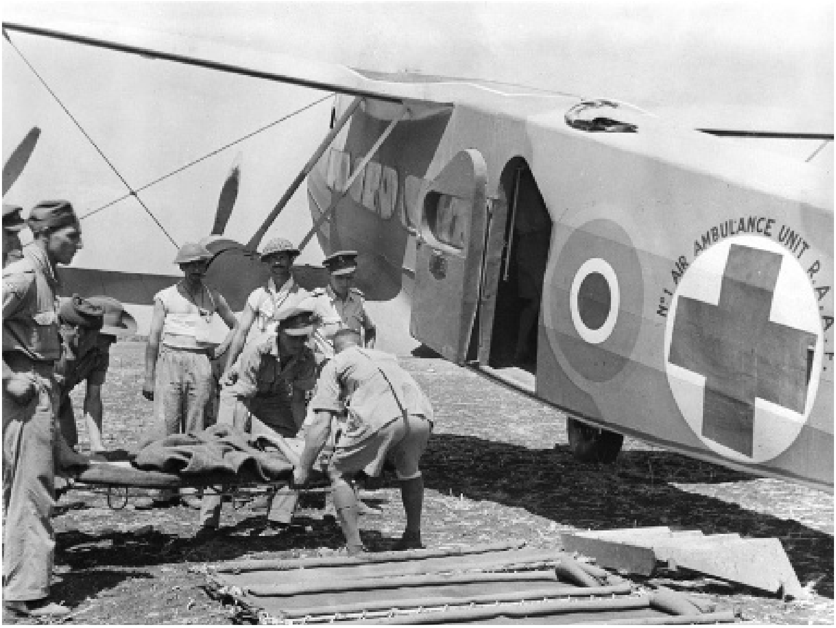
Back in Britain, in 1939, the Air Ministry had no policy on AE but this did not stop casualties arriving by air from the continent as little as 25 days after the declaration of war. Halton became the destination for the patients because some of the casualty clearing stations had yet to open. Furthermore, the aircraft involved were mostly slow-flying transports only able to operate in daylight hours. With its being October, combined with the fact they were not allowed to stay overnight on the Continent, the timings were tight and the aircraft were unable to wait in France for any length of time. To make matters worse, Halton had no ambulances and the British Red Cross had to loan vehicles to move casualties.

In December 1939 these arrangements were terminated when, the Air Transportation Service came to an end with supplies going by sea

One of two Oxfords made available for ambulance duties in 1940; this one lasted for less than a year, although its companion survived until as late as 1948. (MAP)

but valuable experience had been gained and the AASF's Principal Medical Officer wrote to the Director General of Medical Services laying out a plan for strategic and tactical aeromedical airlift, similar to the system we have at present in Afghanistan. By the summer of 1940 two Oxfords had been made available for AE; many more were needed, of course, but at the time *all* aircraft were scarce and many of those that were available were obsolescent.

What was to be done? Commanders on many fronts, particularly the Western Desert, were crying out for troop-carrying aircraft, not even AE specific, to evacuate casualties. Requests to the Air Ministry had to be denied, because there simply weren't enough aircraft. The first signs of help came from Australia when the RAAF sent its No 1 Air Ambulance Unit to Gaza in April 1941. It had three DH 86s, with crews and maintenance staff, each able to carry six stretchers and two sitting cases. This was welcome news but, given that it was based in Palestine, and in that year casualty numbers increased tenfold, it was hardly enough. In the absence of dedicated facilities, the only option was to rely on the principle of 'stores up, casualties back', using whatever means of transport was available, with MOs arranging for aircraft returning to the Canal Zone from forward airfields to carry



A stretcher case being loaded into a DH 86 of No 1 Air Ambulance Unit, RAAF.

patients under makeshift conditions. No 1 Air Ambulance Unit eventually began operating in the Western Desert in August 1941 and at much the same time a number of RAF Bombays and a SAAF Lodestar were also made available for aeromedical work..

Various unique circumstances here led directly to the concept of holding casualties for the aircraft, rather than the other way around. Fuel of the correct octane rating and spare parts for the air ambulances were hard to come by, so again ordinary transport aircraft were used. They could not wait and so the Casualty Air Evacuation Centre (CAEC) and Wing Sick Quarters were developed. This allowed the patients to be ready to board as soon as an aircraft had landed and also allowed treatment and feeding as required. Incoming blood was held in mobile refrigerator vans and distributed locally. These concepts were thought up simultaneously in various loci and without central input. It was an evolutionary process born out of necessity. Following the Battle of El Alamein in October 1942 the 8th Army advanced westward into Cyrenaica and as it moved further from the Nile delta it relied increasingly on air delivery of stores and the evacuation of casualties by air. This reinforced the need for CAECs.

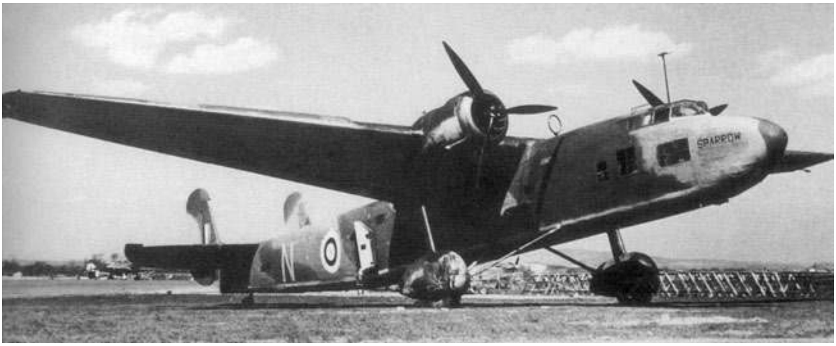
Montgomery's famous 'left hook' at El Agheila in December 1942 provided a classic example of the value of AE. This manoeuvre had involved the New Zealand Division's travelling over rough ground to attack the enemy's flank. The terrain was not suitable for road ambulances but they did carry a Casualty Clearing Station (CCS) with them which had previous experience of casualty evacuation by air. Two landing strips were laid out, permitting the Bombays and the Lodestar to deliver supplies and to fly out 420 patients. By the close of the North African campaign about 12,000 Commonwealth and 18,000 American casualties had been evacuated by air. The use of transport aircraft was now well established, with the RAAF's pioneering No 1 Air Ambulance Unit still doing good work, but the majority of patients were still being moved without in-flight treatment.

Operation OVERLORD

During the preparations for Operation OVERLORD, the Air Ministry had recognised the need for air transport to be used to recover the wounded but, despite repeated attempts to persuade the Allied Expeditionary Air Forces of the benefits of air evacuation, the planners insisted that it would not occur until D+40. This was a travesty, especially when it had proven so effective in other theatres.

Despite this constraint, plans were made to transport an estimated 600 casualties a day using Dakotas and converted Harrow bombers. The plan was to receive the casualties in the UK at No 46 Group's three main bases, all of which were close to Swindon and the RAF hospital at Wroughton. The UK bases exercised regularly from April onwards in preparation for casualty reception. Onward movement of the patients from Wiltshire was to be by train to hospitals in Birmingham. This endeavour saw the first recorded use of 'triage'. The CAECs used a system of three cards, 'A', 'B' or 'C', hung around the patent's neck. 'A' was for patients who needed surgery within 6 hours. 'B' was for cases that it was thought would remain stable for at least 20 hours and 'C' was for head, chest and burns patients. 'A' and 'C' were 'priority'.

In the event, common sense prevailed as regards AE and the first



An erstwhile Handley Page Harrow bomber after conversion into a so-called 'Sparrow' transport. (MAP)

patients were airlifted out on D+7 when the first Dakota landed in Normandy and repatriated twenty-four patients to Blakehill Farm. However, as in the early days in Egypt, this had been another local initiative. Although the arrangements for moving casualties back through the chain from CAEC to Forward Staging Posts and then on to England had been established, the personnel needed to run the system were not yet in place. An account from an unnamed MO in charge of the improvised plan makes clear the difficulty of the task.[4] The airlifting of supplies and personnel into Normandy meant that there were plenty of empty aeroplanes available and it was relatively easy to arrange for these to carry the wounded back to the UK. The problem was one of co-ordination, of matching casualties with aircraft on different airfields each day. It would have been easier for the aircraft to stop on the return journey at a fixed location, but this was vetoed by the AOC. Thus the medical staff in the field had to be highly mobile, while retaining the ability to hold patients, if necessary, while maintaining their treatment. The biggest problem (and this hasn't changed much even now) was establishing the ETA of incoming aircraft, because poor communications with England meant that this rarely turned out to be the ATA.

Nevertheless, despite the difficulties, between D+7 and D+25 more than 2,000 wounded were flown out, see Figure2.

During this same period, the CAECs supplemented their facilities by foraging and commandeering whatever equipment and transport they needed, including a horse and two locals whom they had treated

Date	Location	Airlift out
13 June	B2 Airfield (Bazenville)	50 patients
14 June	Despatched to B3	
15 June	B3 (Ste-Croix-sur-Mer)	115 patients
16 June	B2 (Bazenville)	220 patients
17 June	B5 (Camilly)	267 patients (returned to B2 under shell-fire)
18-24 June	B4 (Bény-sur-Mer)	203 patients on June 18
25 June	B11 (Longues)	208 patients (first death)
26-27 June	B10 (Plumetot)	Moved on
28-29 June	B6 (Coulombs)	233 patients
28-29 June	B8 (Sommervieu)	730 patients

Fig 2. Casualties Airlifted between D+7 and D+25.

and who had subsequently volunteered to become *de facto* orderlies.

Back in the UK, the reception centres were being overwhelmed, but coping. The 'ABC' system of cards was useful but doctors were erring on the side of caution and putting patients into the 'A' or 'C' groups, lest a man categorised as 'B' be condemned to suffer a 24-hour delay to his treatment. Furthermore, the walking wounded had automatically been put into 'B' and stretcher cases had automatically been put into 'A'.

This system obviously de-prioritised seriously ill patients, since a soldier could be walking with a serious internal injury or be stretcher-bound with a simple fracture of a small foot bone. A further contributing factor to the overwhelming numbers of seriously ill was that casualties evacuated by air were not representative of the normal casualty spread of 10% serious and 90% walking wounded. Investigation by the Ministry of Health found that cases were being pre-selected for air transport, particularly those destined for group 'C'. By early October the organisation in England had become more streamlined and Blakehill Farm was closed, followed by Broadwell, all incoming patients subsequently passing through Down Ampney. Over the next six months the numbers transferred by air gradually dropped from a peak of more than 12,000 in August 1944 to fewer than 1,000 in January 1945, partly due to poor flying weather but also due to bigger Army hospitals being established in France. Figure 3

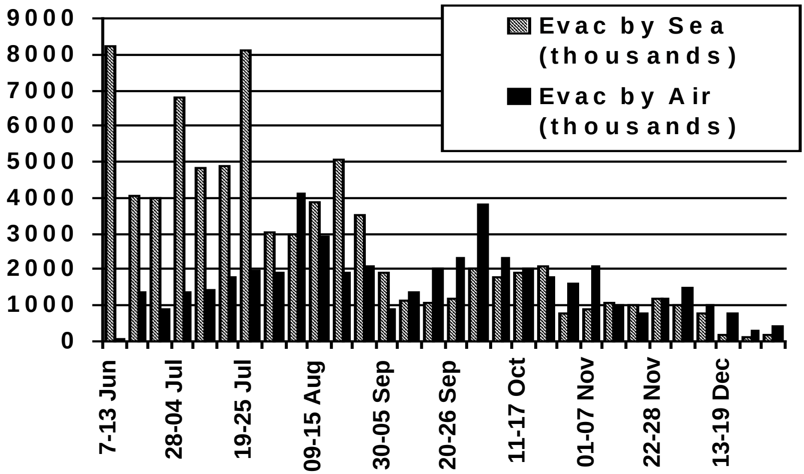


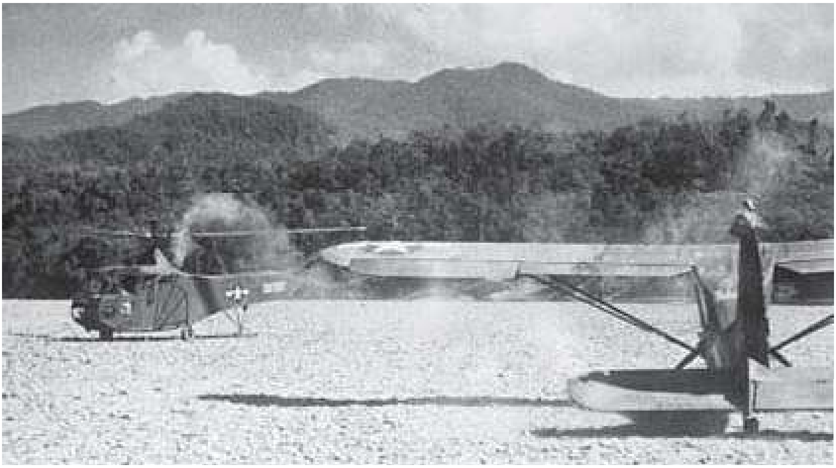
Fig 3. Casualties Airlifted between D-Day and December 1945.

conveys some impression of what was achieved.

Rotary Wing

Since some 72% of the country is forested with teak[8] there were relatively few landing strips in Burma, which made collection of troops almost impossible by air, even if they were wounded. The alternatives were many days of marching, or being borne on a stretcher, to get to a hospital for serious injuries. The following account of the first recorded use of a rotary wing aircraft to move casualties, signposted the next major advance in AE.

> 'In late April 1944, 1st Air Commando sergeant pilot Ed 'Murphy' Hladovcak crash landed his L-1B light plane in Burma with three wounded British soldiers aboard, deep behind Japanese lines. On April 25-26 Lt. Carter Harman of the 1st Air Commandos flew a Sikorsky R-4B helicopter behind enemy lines to them. He flew from his base in India on a circuitous 500 mile route to avoid the Japanese and stopped for fuel every 100 miles at landing zones controlled by friendly ground commandos. He then flew to a clearing near the crash site to pick up the first wounded British soldier and took him to an emergency strip prepared by British commandos on a sand-bar



The Sikorsky YR-4 and one of its Stinson L-5 escorts en route to the rescue of an injured US soldier in central Burma – January 1945. (National Air and Space Museum, Washington DC)

> 10 miles away. He went back and picked up the second soldier, but an overheated engine forced him to remain at the sandbar overnight. He went back the next morning to get the third man and then back again and got the L-1B pilot. The last two R-4Bs of the 1st Air Commando Group were credited with 15 successful evacuations before the two helicopters collapsed from the weight of the jungle's environment.'[9]

Another well-documented rotary wing mission took place on 17 January 1945 when a group of American fliers was downed in Burma and Army Air Forces HQ in Washington dispatched a YR-4 helicopter to effect a rescue. The helicopter was dismantled and flown to Burma in a C-54 transport. By the time it arrived the downed fliers had already been rescued but the helicopter was assembled nonetheless. This was fortuitous, given that within 24 hours it was reported that a soldier at a remote weather station had accidentally shot himself through his hand. The wound had become infected; the hand was badly swollen and the anticipated walk-out time to the nearest medical care was ten days. It was decided that a rescue was feasible and there followed a monumental effort to bring the soldier to medical care.

Since the helicopter had no radio, it was accompanied by a pair of L-5s which had to circle continually to stay with the YR-4. The journey consisted of multiple hops to the weather station using sandbanks as landing sites. Turbulence, together with low fuel and oil forced the pilot to spend the night on the mountain ridge but the next morning he successfully moved the patient to Sinkaling where he was transferred to an L-5 and flown out to medical care at Myitkina. It is unclear as to whether it was involved in any more rescues but it did stay in the jungle and help in search and rescue efforts.

In 1950, in an effort to overcome the difficulties imposed by the inhospitable terrain in Malaya, the RAF set up the FEAF Casualty Evacuation Flight, its initial complement comprising three Dragonfly helicopters, three pilots and a total of sixteen technical personnel.[10] The Dragonfly was notionally capable of lifting a medical attendant plus two patients carried in external pods and had a hoist with which it was theoretically possible to use a ‘boatswain’s chair’ to winch people up from even the smallest of clearings. In practice, the Dragonfly’s performance in Malaya was so severely limited that it was barely capable of lifting one pod, let alone two, and using the winch was quite impractical. Instead, a locally designed and manufactured lightweight (steel and canvas) platform was installed diagonally across the cabin floor onto which could be lashed a coffin-like wicker basket containing the casualty. It was rarely possible to carry a medical attendant and such in-flight care as could be administered fell to the crewman, who had other vital actions to perform. Despite the many problems which it had to overcome, however, in the course of its two-and-a-half year existence, the Casualty Evacuation Flight successfully flew out 265 injured men.

Korea and Vietnam

The casevac (casualty evacuation) chain in the Korean War was unchanged from that of WW II, although the value of AE had led to established CAECs in close proximity to landing strips. Extensive hills and mountain ranges led to further exploitation of the helicopter as a means of casevac. The Bell 47 is probably the most recognised helicopter of this era and its great success in casevac (it was originally in theatre to pick up downed aircrew) led directly to it becoming a dedicated US Army asset for this role. Unlike the Dragonfly, the

The US Army's iconic 'Huey' of the Vietnam War. This 'Dustoff' ship belonged to the 498th Air Ambulance Company which was based at An Son in 1968.

Bell 47 retained a two-pod capability and, since there was only one pilot, there was also space for a seated casualty.

The next major advance occurred in Vietnam when it became possible to tend to the wounded during rotary wing flight. As a first step, in 1962 the US Army deployed a dedicated unit equipped with UH-1 Iroquois helicopters, the 57th Medical Detachment (Helicopter Ambulance). This unit had some capacity to administer immediate aid and pain relief and by the time that the Americans withdrew casualties were often receiving this care within 30 minutes of sustaining their injuries. When the 57th had first arrived in-theatre, however, little use was made of it, apart from cannibalising its aircraft to resolve logistic problems elsewhere and there was even a move to absorb its resources into the general pool of support aircraft. The attempt to clip its wings/rotors was resisted, however, and by mid-1963 the potential of 'the Dustoffs' (from their radio callsign) began to be fully exploited. By 1973 the 57th alone had airlifted more than 100,000 casualties – almost a quarter of the total picked up by helicopters – many of them ARVN troops.

Recent History

The principle of administering in-flight medical care in rotary wing aircraft, as established in Vietnam in the 1960s, has become accepted practice and the introduction of increasingly capable helicopters has

Seen here at Ascension Island, the RAF team that used an air transportable isolator to convey a Lassa Fever patient from Sierra Leone to the UK on 8 March 1985.

permitted this care to become increasingly sophisticated. Indeed the winchman in today's RAF search and rescue helicopters are qualified as paramedics. Furthermore, medically qualified personnel (and the aircraft in which they are carried) are now routinely deployed much further forward than was the case in the past.

In 1982 the focus of the UK's armed forces was on Europe and the Cold War. As a result, when the Falkland Islands were invaded, there was no readily available, pre-planned evacuation chain to facilitate the movement of patients over almost 8,000 miles. A system, involving all three Services, had to be rapidly, and very successfully, created from scratch. It involved naval Sea Kings moving patients from the Regimental Aid Posts to Advanced Surgical Centres and from there to the SS *Uganda*, which had been requisitioned and converted into a hospital ship. Three smaller ambulance ships then ferried patients to Montevideo for transport by VC10 or TriStar back to Brize Norton.[11] These aircraft had medical teams aboard, including medical officers to continue treatment during the long flight home. This, and the following years of routine 'Falklands Runs', led to a steady increase in the level of professional attention that could be offered to patients, transforming the journey from a simple transfer to the provision of critical care to a degree that had never previously been possible.

In 1985 a further landmark aeromedical evacuation was carried out when the air transportable isolator was used for the first time to repatriate a patient with Lassa Fever from Sierra Leone. The patient was flown to Filton for onward transfer to Ham Green Hospital where he made a full recovery. Lassa Fever is an extremely infectious viral disease and requires great skill to care for the patient on the ground, let alone in flight. The isolator allows the patient to remain on his stretcher and function relatively normally whilst being able to interact with the medical staff without risk to them. This service is still in use today.

Within 100 years transport by air has progressed from fantasy to becoming an indispensable part of the movement and continuing care of patients, not only in the armed forces but also where great distances or inhospitable terrain are involved. The function has also changed, having started simply as a means of transport, it has evolved into a mobile platform from which to sustain care and initiate treatment as required. These processes continue to evolve and I am proud to say that today the Royal Air Force gives the best possible in-flight treatment and care to all of its patients.

Notes:

[1] Corbet, A A G and Nelson, D G M; *Canadian Medical Association Journal*, Vol 72 (1955), pp111-116.

[2] Reiter, B L; Executive Research Project: 'The History of Aeromedical Evacuation and the Emerging System of Tomorrow', Industrial College of the Armed Forces, Washington, DC, 1993.

[3] Lam, D M; *Aviation, Space, and Environmental Medicine*, Vol 59 (1988), pp988-991.

[4] The RAF Medical Services (The History of World War II), Vol 1, Chap 10.

[5] Glyn, A S; 'Transport of Casualties by Air 1919-1938', *Medical Training Establishment Journal*, Dec-Jan 1943-44.

[6] Treadgold, H A; *Journal of the Royal Army Medical Corps*, Vol 45 (1925) pp333-338.

[7] Harsch, V; *Aviation, Space, and Environmental Medicine*, Vol 77 (2006) pp73-76.

[8] Keating, T; 'Forced-labour Logging in Burma; Draft: Second in the Rainforest Relief Reports Series of Occasional Papers; In Co-operation with the Burma UN Service Office of the National Coalition Government of the Union of Burma.', June 1997.

[9] Talking Proud, (online magazine http://www.talkingproud.us/Military012106.html)

[10] Dowling, John; *RAF Helicopters, The First Twenty Years* (London, HMSO, 1992) pp36-52.

[11] Bricknell, M C M; *Journal of the Royal Army Medical Corps* 2003, Vol 149, pp85-95.

RECOLLECTIONS OF AEROMEDICAL FLYING TRIALS

by Surg Cdr Herbert Ellis

Herbert Ellis qualified as a doctor in 1944. Having joined the RN, he served in Malta and at Gosport before gaining his 'wings'. After a stint with No 826 (Firefly) Sqn, including time aboard HMS Indomitable, *he was posted to Farnborough in 1950 and in 1959 he became the RN exchange officer with the USN's Naval Air Development Centre at Johnsville PA, where, he worked on G, including problems associated with the X-15 programme. By the time that he left the Navy in the 1960s to work in industrial medicine, he had logged in excess of 2,000 flying hours in more than 100 types of aircraft.*

I feel that what I have to say would be more appropriate as an extract from one of Somerset Maugham's short stories, and in that spirit I will spend a few moments in self indulgence, as well as serving as an introduction to this talk.

My father introduced me to flying. He had been in the RFC, founded Newcastle Flying Club and airport and took me flying – landing on the Northumbrian beaches, sitting on my mother's knees, in the club's Gypsy Moth. (What would the Health & Safety Executive say about that!?) Incidentally, many years later, I always wore his RFC wings under the lapel of my Navy uniform. In due course I also taught my son to fly, and my grandson also flew – four generations, which begs the question – when might 'flying aptitude' become hereditary?

Father and I had one further common factor. He fractured his 6th cervical vertebra when he was shot down in WW I. I sustained the identical fracture whilst simulating high G on a rocket sledge many years later.

Now to Aviation Medicine – an Introduction – if somewhat rambling. The jet engine was invented in the mid-1930s, but it was not until the '50s that the exploitation of the jet gathered pace. Those of us who were fortunate enough to be associated with British aviation during the late-1940s and the 1950s were privileged indeed as we vied – with the USA in particular – in the race for the lead in air supremacy, as the piston-driven aircraft was overtaken by the new jets.

In the early days (130 mph/12,000 ft) aviation medicine made its modest contribution by keeping aircrew insulated against the cold, providing some use of oxygen and medically examining them for basic shortcomings, such as poor eyesight, high blood pressure, etc.

By the end of WW II, medical influence was beginning to make itself increasingly felt, and the term ‘ergonomics’ (derived from the Greek *ergon* – ‘work’) was coined. I was a member of that early post-war aeromedical community. The Spitfire and similar aircraft came into prominence in the early 1940s and, in a belated attempt to bring the Fleet Air Arm up to date, the Seafire was created, but with only limited success, because the aeroplane, and especially its undercarriage and arrester hook, wasn’t really tough enough for carrierborne operations.

The RAF, being a ‘go-ahead’ Service, had always encouraged its doctors to fly, and in pre-war days had granted them their ‘wings’ once they had flown some 30 hours solo. In an effort to emulate this sensible practice, a naval aviation surgeon, with some, if limited, pilot experience was encouraged to do a deck-landing in a Swordfish aboard HMS *Argus*. He gave himself such a fright that he promptly repaired to the wardroom bar, ordered a large gin, and vowed never to do it again – and he never did.

By this time (shortly after the end of WW II), it was apparent that the Seafire had not been the success aboard aircraft carriers that its land-based cousin had been, and it was clear that, due to the high accident rate, the Navy would not be able to sustain a ready supply of serviceable Seafires – or other aircraft – for their carriers east of Suez.

That said, to do justice to the Spitfire’s excellent qualities as a land-based aircraft, it is only fair to record that, in 1944, two different Spitfires recorded true airspeeds in excess of 600 mph (M.89) in a dive, although the propeller came off the first and the engine of the second caught fire and the aircraft was destroyed in the subsequent forced landing.

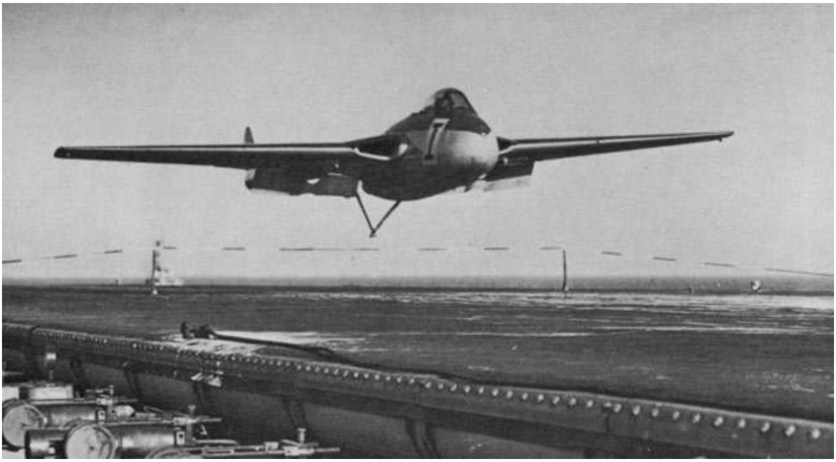
Nevertheless, the accident rate aboard carriers was causing considerable concern and the Admiralty sought the assistance of the

Much of the work of the naval element of the IAM was aimed at reducing the accident rate at sea. This Firefly, MB403, of No 767 Sqn came to grief on board HMS Illustrious *on 8 November 1948 when the port oleo collapsed following a heavy landing; ironically enough, the pilot was a flying doctor, Surg Lt Cdr F A Lennan.*

Naval Medical Department. Quite coincidentally, at about that time I was the MO at Gosport where I was being encouraged to go solo by my Cabin Mate – a flying instructor, Lieutenant (later Admiral) Ian Robertson. My luck was in. Ian decided to allow me to go solo (unofficially), and at the same time, their Lordships announced that they were seeking a suitable Medical Officer to go on a full flying course, including deck-landing, followed by a short period in a front line squadron. And that turned out to be – me.

I became a fully qualified Fleet Air Arm pilot – with a course as a Deck Landing Control Officer (Batsman) thrown in, which proved useful later on as an added qualification – and in due course I was posted to the RAF Institute of Aviation Medicine at Farnborough.

My terms of reference were remarkably vague. I was to relieve Surgeon Commander Geoffrey Linton – a non-flying Naval Surgeon (with a good deal of charm!) whose terms of reference had been equally brief – '*Naval Medical Liaison Officer*'. The problem with vague terms of reference ('Just keep an eye on what is going on, old



An undercarriageless Sea Vampire, about to touch down on the ultimate development of the flexible deck as fitted to HMS Warrior.

boy') – is that they may make you appear to be a 'spy' – the age old rivalry between the two Services was in full spate!

I was soon in trouble! My Boss was Wg Cdr Pat Ruffell-Smith, an eccentric RAF medical pilot (who, later, had the unique record of being awarded an AFC and two bars) who had carefully acquired a stable of aircraft 'for IAM use'. Pat, initially at least, regarded me with a good deal of suspicion, and I was more or less confined to a Griffon-engined Spitfire Mk 22 in which he asked me to conclude a programme of G-suit development work. As a result, I probably spent more airborne time in excess of 7G than less, but I was gradually integrated into the more general flying scene.

This included the flexible deck that was about to be 'flight-tested' and it nearly proved to be my downfall. It involved a modified Vampire (with a strengthened underbelly but no undercarriage) landing on a fabric 'deck' supported by pneumatic balloons, in effect a kind of trampoline. The idea was to use it on aircraft carriers and, possibly, as a mobile airfield for use ashore, the advantages being to avoid the time and expense involved in constructing a permanent runway plus a considerable saving in airframe weight, at the cost of more complicated ground handling and having to launch via a catapult. So far as the trials were concerned, these involved approaching the 'deck', about 10 knots above the stall, over Farnborough's Black Sheds and then rapidly losing about 40 feet (and any excess speed), hoping that the Goblin would respond by picking up the revs. It didn't! – and I finished by going *under* the arrester wire, off the end of the mat and tobogganing across a short length of grass. My only excuse was that, immediately prior to this episode, I had just stepped out of a Lincoln which was comparable to landing a 747 in terms of cockpit height….

The only reason I tell this story is that Pat had been forbidden – by the Air Ministry – to participate in these rubber deck trials, as he was 'precious'; and 'anyway IAM now had an expendable <u>Naval</u> medical pilot at Farnborough, so use him!'

Having bent the Vampire a bit, I feared that my career at IAM might be finished. To my surprise, however, Pat showed his true strength of character, and said that I was to familiarise myself on each of the 'lab' aircraft, as we had to work 'as a team'. That meant, the Canberra (in spite of my having a critical thigh length); Balliol; Meteor 7; a prone Meteor; and the Spitfire 22, and – later a naval Firefly, followed by a Sea Hawk. We also had access to many of the prototypes that came to Farnborough for evaluation.

Meanwhile, my attention was focusing on how pilots used their eyes whilst deck-landing, and how critical the eyes were whilst adopting a slower, but precise, airspeed on the approach – as would be called for during deck-landing.

In the Meteor 7, we fitted a mirror in front of the pilot, and a camera behind him. This revealed two things. On the approach, pilots ceased to blink and concentrated on watching the airspeed – hardly surprising for a slow approach. On touching down they resumed blinking at an accelerated rate – as though to keep up with arrears of ocular 'housework'.

This led to the development of a means of providing an auditory indication of airspeed so that the pilot could look where he was going, instead of having to spend so much time, 'heads down' focusing on the ASI. A rather similar system is now widely used as a 'parking aid' in cars (sadly I did not patent the principle!) – more of this later.

Meanwhile it was clear that I still had a major task to complete – I needed to get Pat Ruffell-Smith qualified at deck-landing, and thus secure his support for investigations into the high deck-landing accident rate.

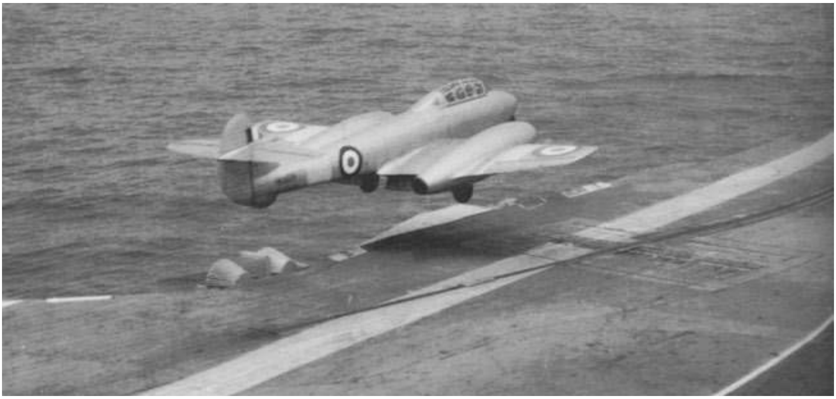
This called for some preparatory work – so the implications of the term 'liaison' were becoming clearer. I started to practise my diplomacy skills on the Commanding Officer of the IAM – Group Captain 'Bill' Stewart – arguably the West's foremost aviation medicine specialist – and, having carefully prepared the ground (he was not a practising pilot), I persuaded Bill that he should complete his aviation experience by demonstrating his 'confidence' and allowing me to fly him aboard an aircraft carrier in our Firefly. I rang round my naval friends, and found a willing seagoing Firefly CO who accepted me, as he was short of pilots to participate in some live firing practice over Dartmoor before embarkation. I agreed, with some diffidence, because the Geneva Convention has some reservations about Medical Officers firing live ammunition.

The next day, the weather was poor, with low cloud, and rough seas, but we managed to fire some live rounds (I was told I killed a sheep!) before finding the ship (HMS *Theseus)* heaving about in the Channel and successfully catching a wire, before returning to Farnborough. Bill's verdict was, '…better than arriving at Heathrow, but glad we didn't participate in the water splash!' – and he recommended his experience to Pat Ruffell-Smith, urging him to follow suit.

However, that was only the beginning (remember this project called for the exercise of my diplomatic skills!) because Pat was adamant that he could not spare the time to do a six-week deck-landing course. However, I now had a powerful ally in 'Bill' Stewart – the CO, and now the only other member of the IAM to have experienced – albeit as a passenger – an actual deck-landing!

Luck next favoured me while I was attending a 'showing the flag' party aboard *Ark Royal* anchored in Torbay. I was 'cooling off' on the quarter deck, when I met the Commanding Officer (Captain Dennis Campbell) – who was a co-designer of the 'angled deck'. I approached him – 'Sir, I see you are going to sea in two day's time – might I borrow your deck for about 20 minutes?'

'Oh, we're going to sea are we? Nobody seems to keep me informed – but certainly.' Campbell said, 'Better make a signal to Admiralty, in case you finish up in the sea. What will the aircraft be?' I told him that it would be a Meteor 7 and apologised for not being



The IAM's Meteor T7, WA619, doing a 'touch and go' on HMS Ark Royal.

able to stop – as it didn't have 'a hook'.

Excited, I told Pat we were going to sea, and persuaded him that he needed to do a few 'dummy deck landings' to adapt to the habit of slower than usual approach and landings. Next day we were off to visit *Ark Royal*. What then took place warrants recording in the history books – Pat was the oldest man ever to have done a first 'deck-landing'. After an initial try, when I flew the aircraft from the back seat for a 'touch and go', Pat repeated the exercise himself a few times before we returned to Farnborough.

This met the Admiralty's requirements before participating in deck-landing. And here I quote……

> 'No one must do a deck-landing until, either, he has completed a formal course in deck-landing or he has <u>done</u> a deck-landing.'

As projects for the Fleet Air Arm began to accumulate, especially those associated with deck-landing problems, the Admiralty allocated a current front line naval aircraft to the IAM for our experiments – including the audio airspeed device. Our Firefly was duly replaced by a Sea Hawk. Unfortunately, it was one of the early production models and thus unpressurised, which gave me a problem later on. As soon as an experimental airspeed warning system had been installed, I sought a carrier-based squadron of Sea Hawks, and joined them en route to Gibraltar in order to try the new device under open sea conditions.

This I did, with favourable results and, assisted by the audio warning of airspeed, deck-landing became as straightforward as a runway landing.

While the trials had been trouble-free, my trip home was less so. To begin with, the Sea Hawk was the first military aircraft to be permitted to fly over Spain since the Spanish Civil War, and a mandatory refuelling stop was required at Madrid, with which I complied, being interested to observe in the process, a number of Heinkels, Messerschmitts and other ex-German aircraft, on the ground.

I made a couple of low passes over Madrid, (by invitation!) before landing. Partly from habit (I had been flying from the carrier), I folded my wings, and Air Traffic announced 'Senor – your wings – they have collapsed!'

After refuelling, I resumed my flight home, but things got a lot worse on the second leg because my Sea Hawk was not pressurised! Running into bad weather, I climbed to maximum height – fuel would be critical – and after about an hour, I felt caisson 'pains' ('bends') developing, but, in order to conserve fuel, I dared not descend until I had cleared the front. It was the worst flight I ever experienced.

My second notable experience with the Sea Hawk, concerned Pat Ruffell-Smith. Apart from the Meteor flight, Pat had not fully qualified in deck-landing. So – enthusiastic about indoctrinating an RAF pilot and, better still, a Medical Officer – I found another friendly carrier. This time it was HMS *Bulwark*. The ship welcomed Pat aboard in Portsmouth harbour, and I joined her – with the Sea Hawk – the next day, after she had put to sea. The aircraft was topped up with fuel while I repaired to the bridge to watch events. As we began turning into wind and gathering speed, the Sea Hawk was 'tethered' to the catapult with Pat in the cockpit. The Deck Control Officer gave him the 'full throttle' signal – when, to my horror, Pat gave a 'thumbs down'.

When I hurried down to the aircraft, he angrily pointed to the fuel gauges, which indicated that all of the new fuel had gone into the rear tank only! A near escape indeed – and an excellent example of the importance of vital actions – on land, or at sea.

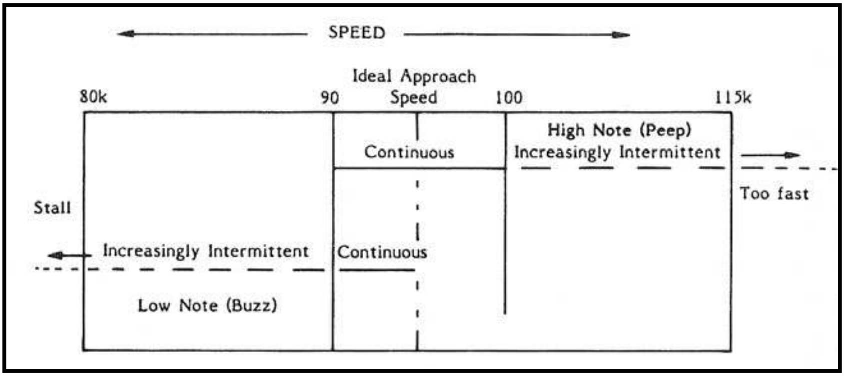
With the passage of time, aviation medicine broadened its scope, in keeping with the expanding field of aviation as a whole. Time only permits me to touch briefly on one or two of the many possible subjects but a good example is the way in which pilots use their eyes – and in the process we can see that not all of the costs involved in pure research were wasted, as the story behind the auditory airspeed/'Parking Aid' illustrates.

While the interaction between the eyes and other senses had been investigated before, of course, it had not been explored exhaustively in the specific context of aviation physiology. It is known that eye movements are influenced by the semi-circular canals – of which we all have two lots of three, located near the middle ear, each at 90 degrees to each other. These canals hold a fluid – endolymph – into which protrude small hairs, which can detect 'rotation' (in any plane) at a rate of change of 3 degrees per second. This, in turn, causes the eyes to rotate – in the associated plane.

Thus, if you are sitting in an airliner, with no external reference, and the aircraft banks into a rate one turn (which, it so happens, is also 3 degrees a second) – the bulkhead will apparently – visually – also 'rotate' – or 'bank'. I was beginning to suspect that the explanation for some deck landing accidents might lie in how the eyes are used – while the ears were unemployed! All of this, incidentally, has a strong connection to motion sickness – but that is another, longer, story.

Professor Geoffrey Melvill Jones was a leading researcher in the field of eye movement and it was a rare honour to be able to work with him. In our efforts to reduce the high incidence of deck-landing accidents, we began to investigate what information pilots needed and what sensory pathways were used to convey this information to the brain. As I have already described, the IAM's Meteor 7 had been fitted with a mirror and camera and we used this aircraft to fly with a wide variety of pilots, many of them students on the current Empire Test Pilot School course. It was interesting to observe the varying degrees of discomfort and/or confidence displayed when they were required to fly at lower speeds than they were accustomed to (only slightly above the stall) during their approach and landing.

Subsequent analysis of the recorded results showed that, during the approach, the rate of 'blinking' steadily decreased, then ceased completely during the 'terminal' phase (an unfortunate turn of phrase, perhaps!) moments before touching down, only to quadruple after landing. It was clear that the visual pathway had become 'saturated',



Audio airspeed presentation – the same principle is at work in audio car parking aids.

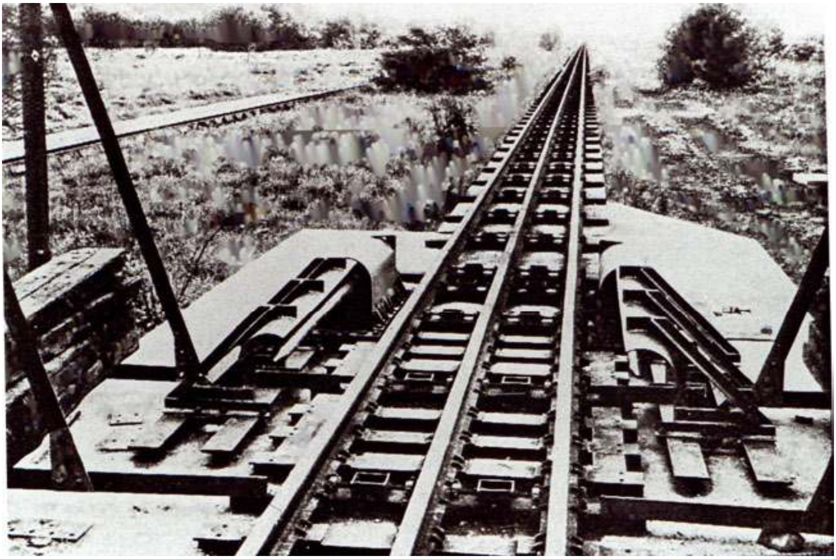
whilst the auditory sense was unused.

This programme confirmed the value of the auditory airspeed device which was eventually installed in the Sea Vixen and Buccaneer, before the whole business of deck-landing was transformed by the introduction of VTOL.

That said, the principle is still in use in the guise of a ‘parking aid’ for motor cars, the audio cues being very similar. Whether dealing with airspeed or car parking, a steady low tone does not demand attention, whereas an intermittent one does, and the more frequent the repetition and the higher the pitch, the more urgent is the need to react.

Another interesting field in which I worked concerned cases of low G threshold. I recall a student being referred to the IAM from Training Command, with a provisional diagnosis of ‘Low G Threshold’. His history revealed that he was at the Provost stage in his course; just commencing aerobatics, he was prone to ‘blacking out’ on pulling any G.

Clinically, he appeared healthy, and nothing abnormal was detected. Blood pressure revealed nothing. His flying assessment was otherwise excellent. I took him up in our Meteor 7 to permit me to assess his general flying, and I found no fault, including some steep turns. After 20-30 minutes, at about 20,000 feet I suggested we try a loop. I gave him the necessary speeds and let him get on with it, but asked that he leave his microphone switched on (I already had my suspicions!). All went well, except that he pulled quite a lot of G until,

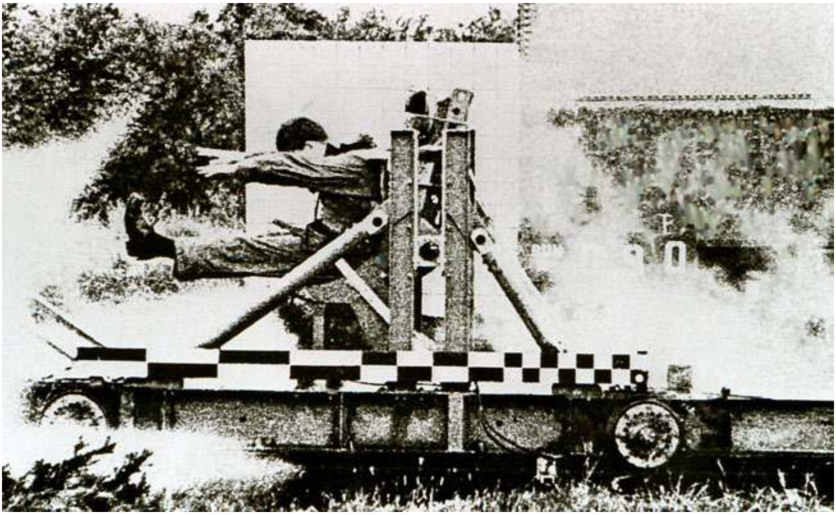


The track at Farnborough used for rocket sled tests.

at the very top of the loop, I was fascinated to observe a classic ‘Epileptiform Seizure’ (the first in my clinical experience). I also noticed that, in the preparatory manoeuvres going into the loop, his breathing had become very heavy and laboured (thus washing out any surplus carbon dioxide from his lungs, as well as most of the oxygen) – precipitating an hypoxic attack, from which he did not fully recover until we were back on the ground.

Resuming my questioning in my ‘surgery’, he confessed that he had become bored with the slow progress of the airborne side of his course and had decided that he would try some unauthorised solo aerobatics. He got into trouble (probably a spin?) and very nearly failed to recover – since when he had been most apprehensive about ‘turning upside down’. With the problem diagnosed as largely psychological, another trip in the Meteor showed him to be an able aviator, quite capable of dealing with loops, and he eventually completed his course.

My final tale concerns some work that I did on linear acceleration. As the reputation of the IAM grew, we were asked to investigate a number of specific problems associated with carrier flying. One of



The Farnborough sled at the point at which it was arrested..

these was provoked by the advent of the Steam Catapult, which gave aircraft a considerable increase in acceleration on taking off from carriers, and it was feared that this might distort vision by flattening the eyeballs.

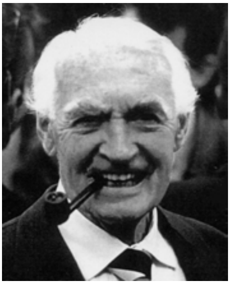
Always willing, we found some rusty railway lines which had been used to train army personnel to drive trains in occupied Europe. We then found an explosive expert who delighted in setting off time-expired rockets. The combination gave us a vehicle capable of propelling a human from 0 to 70 mph in about 1½ seconds followed by clear run over about 400 yards of track before being ‘arrested’ (thus testing the seat harness). This caused minimal damage, apart from one trip in which I participated when I broke my neck – hence the injury mirroring that of my father.

Our operating problems were not eased by the fact that our ‘helper’ was Irish, and his very loud voice and broad accent raised some suspicions amongst the local neighbours (the IRA were quite active in those days).

Partly as a result of those trials – and despite my broken neck – the Steam Catapult was duly certified as being safe to use. And there, I must bring my reminiscences to a close.

Operation HOTBOX

by Air Mshl Sir Geoffrey Dhenin



After completing his medical training, Sir Geoffrey was commissioned into the RAF in 1943. He spent the rest of the war, in the course of which he was awarded a George Medal for rescuing a casualty from a burning aircraft, in Bomber Command and 2nd TAF. He qualified as a pilot in 1946 and, following a number of flying appointments, he spent 1960-66 commanding the RAF Hospitals at Akrotiri and Ely. He was PMO at both Air Support and Strike Commands before ending his Service career in 1978 as Director General of RAF Medical Services. Shortly after he retired, he wrote a definitive textbook on Aviation Medicine.

Ladies and Gentlemen,

It is a great honour to be asked to address you in this hallowed place, surrounded by so much evidence of Royal Air Force history, and in the presence of so many aviation experts who have done so much and risked so much for the safety of our aircrews. I have worked with many of them in a minor role.

When the war with Germany came to an end and the US Air Force dropped the first atomic bombs on two Japanese cities, the world became a new and dangerous place. Even the vocabulary changed. The word 'mad', for example, meant not only a clinical condition but 'mutually assured destruction'. The atomic bomb was in everyone's mind.

Although the Americans had led the research, British scientists had taken an important part in it. On their return to this country they set to work to produce a British atomic bomb. This was exploded at the Montebello Islands. To find out how efficient the reaction had been, rockets were sent up into the cloud to bring down samples which could be taken to the laboratories and carefully checked.

The bomb exploded well enough but the collection of samples was disappointing. Some more efficient and controllable system was required if a satisfactory weapon was to be achieved. The obvious solution was to collect samples from the cloud as it ascended and bring them back. Radio controlled aircraft had not yet been invented so a human crew was required.

At this time I was the Flying Personnel Medical Officer for Bomber Command based at the command headquarters at High Wycombe. My job was to visit all the bomber stations, mingle with the aircrew, listen to their experiences and grouches and liaise with experts at the IAM at Farnborough to find appropriate solutions. In this way I had gained many flying hours and many expert friends. One evening I was at a mess party when I was approached by Group Captain Denys Wilson, whom I knew to be the consultant adviser in X-Ray radiation. He took me into a corner. We chatted for a while and then he asked me, ‘How would you like to have a brand new Canberra of your own?’ I laughed – then saw he was serious. He looked at me and went on, ‘I have a job for you. It is to fly a Canberra to Woomera in Australia and then fly it through the cloud of an atomic explosion to penetrate the cloud to obtain the samples required to assist our scientists to perfect the weapon.’ Astonished at this remarkable revelation, all I could say was, ‘Why me?’ He replied, ‘You have flown about every type of aircraft in the air force and have never even scratched the paint on one. There is also another reason; Napoleon, when asked what qualities he looked for in a general, replied, “I don’t want clever generals; I don’t want brave generals; I want lucky generals.”’ Denys then pointed at a ribbon on my tunic and. said, ‘I have read the citation for this and you must be one of the luckiest people I have ever met.’

The third member of the crew was the navigator. We had to fly out to Australia without any of the navigation aids now available and when the weapon exploded we had to be in exactly the right place at exactly the right time. I consulted the navigation leader of Bomber Command and he immediately proposed himself. I said. ‘Andy I would love to have you, but I happen to know that you have just been given a medical category of permanently unfit aircrew for deafness.’ He replied, ‘Geoffrey, you are a doctor. Surely you can fix it!’ I went to see the ENT consultant, explained that I was about to make a long flight under unusual conditions and that success (and *my* life) depended very largely on the experience and courage of the navigator. Bless the man! He now amended Andy’s category to read ‘Fit to fly to Australia under medical supervision’, ignoring the fact that the navigator’s position was in a separate compartment in the aircraft, out of sight of the pilot, the only means of communication between the two being via intercom. This was also the case for the observer where Denys was to be stationed.

The next step was to go to the English Electric factory to collect the Canberra after the makers had given it a special paint finish which, we hoped, would enable us to clean off any radioactive material acquired during the test. This would be an extra hazard to the crew during the flight home to England and also a security risk. Naturally I, a mere squadron leader, was as proud as punch to have such a beautiful toy – all my own! I flew it down to Farnborough to have a long-range 600 gallon fuel tank put into the bomb bay and a special filter into the starboard wingtip tank to trap the radioactive particles from the cloud. This tank was secured by explosive bolts so that it could be jettisoned by a switch in the cockpit. There were also smaller filters in the fuselage. With all these we hoped to provide ample samples for the scientists .

The final stage in the preparations was a test flight. I elected to fly to Cyprus – far enough to check fuel consumption and the general handling. This flight was not without incident. When we crossed the English coast I asked Andy for the next course and got no reply. I guessed that he had passed out through lack of oxygen as we were at 50,000 feet – our normal cruising altitude. I had no choice but to descend to about 20,000 feet where he regained consciousness, saying his mask was not tight enough. I climbed again; again he passed out and again I descended.

I was becoming anxious about our fuel state. There was a number of airfields within our range, but they were all closed. It was now Cyprus or bust! At last we sighted the coast and the runway. As we touched down all my fuel gauges were reading zero. As we climbed out of the aircraft Andy threw his arms around me and said, ‘Geoffrey, fly with you anywhere!’

Our flight to Australia passed off without further incident. As we entered Australian air space at 50,000 feet I reported our presence to air control, ‘This is RAFAIR (and my number)’. I was asked to repeat the message and after a few seconds came the reply, ‘Good on you mate!’

At Woomera we were royally received, though we had to keep well away from teams of journalists who were there to report on the progress of the England to New Zealand Air Race. Woomera was the last refuelling stop before the end of the race.

Our task was not mentioned in their presence and my aircraft was garaged in a remote hangar, far from prying eyes.

As soon as we were settled I flew up to the weapon site which was next to a dried up lake. We checked our radio communications with the scientific control and examined the best area at which to eject in case of need. The RAAF also produced a Lincoln bomber crew to patrol and to direct the land rescue in case we went down.

We waited at Woomera until the scientists at last radioed that they were ready to fire. I filled in the time by practising my golf swing to the great amusement of our Aussi friends.

Just before dawn we went into the hangar where the groundcrew was waiting. I did my pre-flight checks; we climbed aboard and strapped ourselves in. Then the groundcrew sealed all the joints with Sellotape and pushed us out of and well clear of the hangar doors. I started the engines and taxied to the runway. We had a short delay for the kangaroos to be driven off the tarmac on which they liked to spend the night because the surface was cool.

As soon as I was airborne I heard my escort call, 'How are you feeling mate?' I replied, 'OK, but my teeth are chattering.' 'Well take them out!'

We had arranged with the control site that the weapon would not be fired until I signalled that I was over the dried up lake and heading away so I would not be blinded by the flash. After the flash I would head for the edge of the cloud and put my port wingtip in so Denys could get a reading of the dose rate with his instruments to make sure that the dose rate would not be suicidal. Once I had his assurance, I turned and aimed for the centre. It was then the fun began! The aircraft was flung in all directions. I thought I was losing control and the aircraft would break up. Gradually I regained control and we emerged and very carefully sampled all aspects of the cloud – base, top and the edges.

As we left the area and set course for Woomera I sent silent thanks to English Electric who had built the aircraft so solidly. After this adventure I thought, 'We have seen Dante's Inferno.'

When we returned to Woomera an Aussi Canberra was waiting in the circuit to lead us in for our landing in case our air speed indicator should be damaged, but we had no trouble. There was, however, one episode yet to come. I taxied around to the point where I had set up a pile of sandbags to receive the wing tip sample – the largest and most dangerous of all. It dropped on the concrete as intended, but alas, there was now a strong wind blowing. It bounced on the sandbags and, caught by the wind, it began to roll – right toward my nosewheel. You cannot put an aircraft into reverse. I thought I was going to be known to my pilot friends as the man who left his nosewheel at Woomera! A figure rushed forward and kicked it away from the nosewheel. This brave man, who later died, was the scientist awaiting the sample. He was the only accident associated with our exercise.

I now taxied around to where my friends were waiting at the decontamination area. They took away our clothes and the dosimeters we were wearing and subjected us to a freezing shower, the coldest showers I had ever had. Next day, refreshed by a long sleep, we began work on cleaning the aircraft, ready to sample the cloud of the second weapon, due to be fired at any time soon. We recruited a number of volunteers from the ground staff. We used long-handled brushes and many gallons of soap and water. There was not much we could do about the engines or the interior of the fuselage, so the cabin could no longer be pressurised. We had, however, the outdated pressure waistcoats to enable us to fly at a reasonable altitude, though not high enough to get the most economic range.

I was now summoned to see the chief scientist. He congratulated us on what we had achieved, but I could see he was a worried man. I think the sight of such a fragile machine entering Dante's Inferno weighed upon his conscience. Before I could speak he went on, 'Go home boy; you have done enough. I cannot authorise such a dangerous thing a second time.'

He put his arm around me and said again, 'Go home'. So we did.

Back in England, at a special maintenance unit, the aircraft was taken to bits. The red sand of the Australian desert was still clearly visible in the engines.

I now come to the sad part of the story. Several months later the Americans asked the RAF for help to sample a new weapon they were to test in the Pacific. My crew and I could not accept any more radiation so we trained a new crew to use the radiation instruments. We fed them carefully and sent them off to the Pacific. They took off from Darwin, and were never heard of again. My beautiful aircraft is now lying on the floor of the Pacific Ocean.[1]

[1] The aircraft was WH738, which was lost on 23 February 1954. **Ed**

DISCUSSION

Air Cdre Ian McCoubrey. In view of the constant contraction of the Service, does the panel believe that there is still a future in aviation medicine within the RAF?

AVM Ernsting. Those of you who know me will know that one of the reasons why I have not given up working yet, and why I still try to encourage young people to go into it, is that I firmly believe that aviation medicine does have a future. Whether we have 200 aeroplanes of a given type, or just five, you have still got to keep the pilot as efficient and well protected as possible to enable him to do his job. And to do that, regardless of the size of your air force, you need the same amount of research and back-up.

I am only on the periphery of our latest aircraft projects, but I do have some knowledge of them and I am sure they will be no different from those that have gone before. I have highlighted a number of aviation medicine problems that will need to be solved over the next few years and to do that will require the expertise of the RAF Centre of Aviation Medicine and the participation of the flight medical officers in the field.

One of the things that does depress me about the current situation is the position regarding the education of air force medical officers. In the past, education was, along with research, a prime function of the IAM. Indeed, Air Mshl Sir John Baird, a member of the first long academic course we ever ran at Farnborough, is here with us today. We are currently running No 40 Course, but instead of its having fifteen or twenty RAF medical officers as students, we now have, at Kings[1] and at the Centre of Aviation Medicine, just two. That is, of course, in part a result of the contraction of the air force but it also reflects the problem of persuading medical officers to stay in the Service for a long time so that they can become experts in the practice of aviation medicine in the field.

So, to answer the question quickly, yes, I think that aviation medicine has got a future for as long as we have got men in aircraft

[1] Originally conducted by the IAM, responsibility for the Diploma in Aviation Medicine (DAvMed) course was transferred from Farnborough to King's College London in 1998. **Ed**

and – dare I say it? – for as long as the Chief of the Air Staff is a pilot. We shall not see the end of manned aircraft in my lifetime – so aviation medicine still has an important part to play.

AVM Johnson. I would just add that a UAV is not an entirely 'unmanned' aerial vehicle, as there is still a man, at one remove, controlling it – and men will still have problems.

Gp Capt Tony Neale. I did not recognise the young man in the wheelchair (*referring to a slide that Alistair Macmillan had used to illustrate a trial mounted in 1960 to investigate the phenomenon of 'Hunter lung'*) but I did fly in that trial and recall the slightly insubordinate comments of the groundcrew – and the ripe remarks of the aircrew who were not involved!

As one of Air Mshl Ernsting's slides indicated, and as I recall, the time taken for the lungs to come back to normal was quite significant, yet we continued to fly simulated combat sorties, sometimes three a day, and we were still doing so in 1965 to '67 when I commanded a Hunter squadron. It seems to me that there was an unpalatable diagnosis from that trial. Similarly, I was involved in a trial in FEAF, when we were flying the Venom, with its apology for an air conditioning system. We were strip weighed before and after sorties and some quite alarming conclusions were drawn from the results. Yet, again, we continued to fly as we had done before – and thoroughly enjoyed it, of course. So, to my question – is there, has there been, any difficulty in the relationship between the air staff and the IAM when the IAM's trials have yielded unpalatable conclusions, in that they ran counter to operational imperatives?

AVM Ernsting. In general, no. I think one of the most important functions in our training of our consultants in aviation medicine, as specialists at IAM, was to be able, not only to do the research, but to convey the implications of that research to the air staff – to our customer – to ensure that they understood what we were doing. Certainly, from the mid- to the early-1960s onwards, relationships between the IAM and the central staffs were excellent. With the OR Branches we used to say, jokingly (and perhaps I shouldn't say it too loudly with this audience), that, taking somebody joining an OR office involved with life support and escape systems for a three-year tour, we would spend the first year educating him, the second establishing good personal relationships through visits to and from IAM, and the third year actually getting him to make the right decisions, based on the work done by the IAM.

I spent a year and a half on a sabbatical at the USAF School of Aerospace Medicine in 1979-80 and the thing that really depressed me there was the distance between the people doing the research work at the bench and the people in the Pentagon making the decisions. There were so many intervening layers of command that they had the greatest difficulty in getting the results of their research actually applied to aircraft.

The other thing I would stress about the heyday of the IAM was our very close relationship with industry – with the test pilots and with the aircraft and equipment manufacturers. One of the unfortunate consequences of the loss of the IAM has been the loss over the last ten years or so of its influence on industry. Industry had depended heavily on the work that the Institute did and on the advice and education that it was able to offer. Big gaps are now appearing, both at British Aerospace (and I know, because I am currently working on two of their projects) and at the equipment manufacturers, in that they no longer have decent aviation medical or physiological advice and they certainly don't have access to the sort of practical tests and trials that are essential in the early stages of developing a new weapon system.

Air Cdre Mike Gibson. May I just add something to that. It is not as if the air staff slavishly did everything that the medical officers suggested. They were the executive; we were advisory and they didn't *have* to take our advice, particularly if that advice might have had financial implications over and above what they were prepared – able – to spend. But you knew that they always listened very carefully, and we always fought our case very, very hard.

Wg Cdr Jeff Jefford. With the demise of the IAM, do we still have a centrifuge? – and is it still the 1955 model?

Wg Cdr Nic Green. How long have you got?! It's a very complicated saga. Yes, we still have it – but it is now a Grade II Listed Building! We also have an empty building at Henlow which was to have housed a new centrifuge, but it is still an empty building at the

The old IAM complex at Farnborough which is being/has been demolished to make way for new development.

moment. A contract for a replacement centrifuge was let in 1997 but, for various commercial reasons, that contract was cancelled in 2001. We restarted the procurement process but around about 2003 that programme, along with a lot of others, was abandoned when we encountered problems with our funding within the MOD budget. Nothing has changed since, so we are still using the old machine, but, if you have been to Farnborough recently, you will have seen that the old IAM is in the process of being demolished to make way for a new road and a housing estate. The centrifuge would have been demolished as well, had it not been for English Heritage who, three or four years ago, had put it under notice as a Grade II Listed Building. We have funding to continue to run the centrifuge until 2009 but beyond that is another matter. So, at the moment the Farnborough facility is to close around mid-2009 and we have nowhere else to go, no funding to get another one, no funding to go abroad, no funding to do anything. The problem is currently with HQ Air Command.

AVM Nigel Baldwin. Looping back to John Ernsting's response to the first question, specifically, his concern that we are currently training only two prospective experts in aviation medicine and the problem of retention, could Wg Cdr Ruth tell us something about his situation. He seems to be in a very curious position, working 50% of his time with the military – and right in the front line when he does so – and spending the other 50% with the National Health Service. Is that a symptom of our rapidly contracting air force which, despite its much reduced size, is still heavily committed to operational activities which still require young and dedicated professional men and women. How does it work?

Wg Cdr Martin Ruth. A lot of the problems stem from DCS 15[2] which followed on from the end of the Cold War after which there would, clearly, be no more wars to be fought. I'm no expert in this field, but, as I understand it, offering doctors an option to leave the Service at the point at which they are just starting in a consultancy in their chosen specialisation was pretty much oversubscribed and at one fell swoop the air force lost a huge number of its clinicians. Contrary to expectations, of course, during the 1990s we actually had the fighting in Eastern Europe and we went back into Iraq and so on.

The terms of service for doctors are quite similar to those for pilots and other commissioned aircrew in that there is a '38/16' career break which, for doctors, is at about the time that you become a consultant.[3] So, it's, 'Thank you, for the pension and the lump sum – and thank you for training me, but I'm off to start my lucrative new career.' The logic is not difficult to grasp and one can see why we are losing people hand over fist.

I think we have been through a bit of a crisis, especially with anaesthetists, like myself. What happened in my own case was that I was in a strong bargaining position and was able to ask to be assigned to a hospital in Edinburgh to do my training, completely divorced from the Royal Air force – because the RAF no longer had any hospitals of its own. This was before the establishment of the Ministry of Defence's hospital units scheme, so I received my training, right through to a consultancy, under that system. When I reached the point at which I had an option to leave, I was asked if I would to stay on and

[2] DCS 15 - Defence Costs Study 15 – which was conducted in 1994/95, was the review that led *inter alia* to the closure of the military hospitals. **Ed**

[3] An optional retirement date at the age of 38 or after sixteen years of service, whichever comes later – the so-called '38/16 point' – was introduced in 1960 and has been a standard feature of the terms of service on offer to officers of most Branches ever since. **Ed**

I agreed to do so, if I could stay at Edinburgh. That said, I retain my military obligations, including a permanent training commitment which brings me down to Lyneham two or three times a year. Over and above that routine, however, my operational commitment has increased substantially over the last five years. I am currently one of nine consultant anaesthetists who take it in turns to be at 24 hour's notice to deploy and to operate in the field, often for two to three months at a time. In effect, our present commitments mean that we are away from our families for between 6 and 8 months every year.

Looking at the longer term, there has been a change in the pension scheme which means that there is now a financial incentive for doctors to stay in uniform as consultants when they reach the 38/16 point, rather than leaving which had previously been the only sensible thing to do. And it works – at least, it does for me. I enjoy my career; my family circumstances are different from those of many of my colleagues, so I certainly don't speak for everyone, but the way in which I am employed is not uncommon and a lot of other specialists currently work in similar situations.

AVM Johnson. I should point out that that is the clinical picture. Your question also related specifically to aviation medicine which is practised almost exclusively within the Service; there is very little 'outside' activity.

Mike Meech. We have heard a lot about the man in the cockpit and the equipment made for him but for quite some time now we have also had women in the cockpit. They must have distorted the figures for the average size of aircrew, which must have had an impact on the provisioning of equipment, and women are also supposed to have a better tolerance of pain. Are they better at withstanding G?

Wg Cdr Green. A lot of studies were done on male versus female G tolerance in the USA back in the 1980s and the conclusion, from a large sample, is that G tolerance is essentially the same between males and females. On a theoretical basis, the female's blood pressure is generally a little lower, which might make them a little worse, but this is offset by their sitting height, which is a little shorter – which is advantageous under G. My personal experience, having put many females on the centrifuge, is that they tend to be very good as a general rule, and anecdotally, at least, their tolerance is often better than the males. There is some question as to whether they may become fatigued more quickly if their overall muscle bulk is less than a man's.

In terms of aircrew equipment, yes, it is a problem, and it is not confined to size; shape is another factor. In G trousers, for instance, there is a variation in the ratio of the length of the legs compared to the torso. The proportions are different and, in some cases, we have actually had to redesign kit specifically for females. That said, we have to be careful not to call them 'female garments', of course, because they do equally well for smaller males and they don't want to be accused of wearing 'girls' trousers' – so they are often just designated as a 'small' size. That said, we still don't really have that many females flying and we have been able to manage the situation without too much difficulty.

Dr Alistair Macmillan. When the gender barrier first came down and females were permitted to fly, there was an initial rush, but the numbers appear to have tapered off since. But we do have a very competent female currently flying for the Centre of Aviation Medicine, so their interests are in very good hands.

CHAIRMAN'S CLOSING REMARKS

AVM Alan Johnson

On that note I think I have to draw the proceedings to a close. First of all thank you, the audience, for your attention and for your questions. And on your behalf may I express my thanks to all the speakers who have given up their time to be with us today.

We tried to recount some of the history of aviation medicine in the RAF, a subject often little understood by those we serve but without which we would not be able to operate so successfully and so safely. First we heard from Mike Gibson about the development of medical examinations so beloved by you all. They can sometimes, well often, be curious, sometimes comical, but these examinations are designed to fit the man for the job – and we think we have achieved that goal.

John Ernsting lead us through the creation and development of one of the great centres of research – the IAM – until it's tragic, and in my opinion, criminal closure. He described the dedicated and devoted work of a whole galaxy of medical scientists, both military and civilian, much respected by their profession but, sadly, I have to say, often unrecognised by the Service.

Alistair Macmillan described how essential it was to conduct trials *in situ* and in flight and the importance of the juxtaposition of the IAM to the RAE and aircraft.

Acceleration effects were one of earliest problems experienced in high performance flight and Nic Green took us through the development of the measures and equipment devised to counter this. An initial aeromedical evacuation capability was pioneered by the Royal Air Force and further developed during World War II and subsequently and it is now, sadly, to the forefront of our current medical support. Thank you Martin.

Now without Herbert Ellis's efforts we would not have been assembled here today. He regaled us with his humorous and exciting reminisces of life as a naval medical officer pilot. And finally we are grateful to Air Marshal Dhenin for sharing with us his very unique experience. What today's 'health and safety police' would think of such an enterprise doesn't bear thinking about!

Our time is up. I thank you all for your attention and I wish you a very safe journey home.

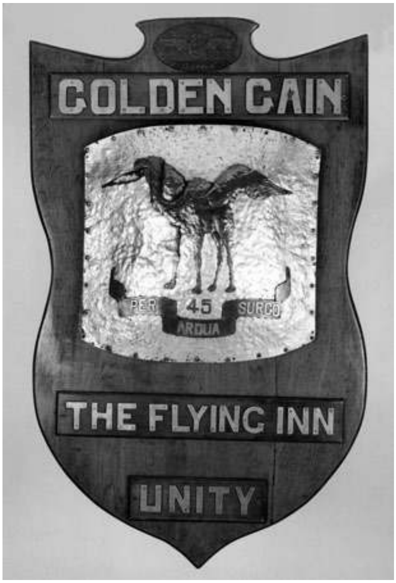
CASUALTY EVACUATION 1923
KOICOL TO BAGHDAD

In Wg Cdr Ruth's paper (*see page 81*), he refers to the evacuation, by air, of some 198 soldiers in Iraq in 1923. This enterprise had involved a dozen Vernons, fielded jointly by Nos 45 and 70 Sqns, operating under the direction of OC 45 Sqn, Sqn Ldr (later MRAF Sir) Arthur Harris. His contemporary report on the operation is reproduced below (the original may be found at Kew within AIR5/1253).

As Wg Cdr Ruth (and the Harris report) describes, one of the Vernons was forced to land and had to be destroyed. There is, however, an interesting follow up to the tale. No 45 Sqn's 'flying camel' emblem was carried on the nose of its Vernons, each of which had an individual name, rendered in brass letters mounted on a wooden batten below the cockpit sill. Before Flt Lt Ian Matheson burned his aeroplane, he salvaged its badge and nameplate, *Golden Gain*, and when he returned to England in 1924 he took them with him along with the nameplates from *The Flying Inn* and *Unity*.

He had his trophies mounted on a wooden shield and they eventually resurfaced in 1960 in Matheson's cottage at Nigg whence they passed into the hands of a Mr Stout, the landlord of the *St Duthus Hotel* in Tain, for use as a bar decoration. The Deputy Assistant

Flt Lt Ian Matheson's Vernon J6882, 'Golden Gain', down on its luck in the mountains of northern Iraq.



Above left, providing some idea of the substantial size of No 45 Sqn's badge as worn on its Vernon and, right, the shield currently in the safe-keeping of No 45(R) Sqn at Cranwell.

Provost Marshal for that part of Scotland, Sqn Ldr Graves, spotted the shield and suspected that it probably originated with an RAF unit. Mr Stout, being ex-RAF himself, was sympathetic and amenable to releasing his recently acquired artefact, provided that a more appropriate home could be found for it. Sqn Ldr Graves contacted the *RAF News* which carried the story. At that time, No 45 Sqn was stationed in Singapore where it was commanded by Sqn Ldr J W 'Jock' Valentine. The CO promptly claimed the shield for the squadron and it arrived at Tengah in August 1961. This rather splendid memento has been among the squadron's most prized possessions ever since. It is currently held by No 45(R) Sqn at Cranwell.

CGJ

Ref: No 45/Air/5/Op

No 45 Squadron
Royal Air Force
Hinaidi
Iraq

Dated 5 May 1923

To:- Air Headquarters (Air Staff)
British Forces in Iraq
Baghdad

EVACUATION OF SICK FROM KOICOL TO BAGHDAD

1. Attached are details of the flights made in connection with the above operation.

2. The first two days of the work were characterised by very bad weather conditions for the type of machine in use. Bristol Pilots with several months experience of mountain work stated that during those two days they experienced some of the roughest weather they had flown in. Vernons had to be got up to at least 5,000 ft. before control could be retained crossing the Adghir Dagh; and before the effects of the strong air currents over this ridge were realised by all pilots VV 6882 (*ie Vickers Vernon J6682* **Ed**) was brought down from 3,000 ft. with both engines full on and running well, and crashed. This may sound like exaggeration but any Vernon pilot who flew in that locality on those days will corroborate the probability of this occurring if any attempt were made to cross the ridge below 5,000 ft.

3. VV 6682 having crashed in inaccessible country where hostile patrols of Sheikh Mahmud were present, had to be burnt. The sick were brought in by Wing Commander Treadgold and the Pilot on mules and donkeys to Koi. They seemed none the worse for their experience and the unavoidable crash was so skilfully managed by the Pilot, Flight Lieutenant Matheson, that one of the sick men had to be awakened and told to get out. Flight Lieutenant Roberts of No 6 Squadron made an extraordinary skilful landing near the crash, on a piece of ground so small as to make landing seem an impossibility, under weather conditions that whilst assisting him in getting into an astonishingly small space, yet left him practically no control over his machine near the ground: He took out Wing Commander Treadgold, RAFMS and brought back the most seriously ill patient, undoubtedly

saving his life; and enabling the remainder to receive medical attention that helped them through the long ride to Koi without serious after effects; I consider Flight Lieutenant Roberts deserves the greatest credit for his action on this occasion. There was no possibility of landing other machines there to fetch the sick in, without crashing the majority.

4. The policy was to use the best machines and pilots on the mountainous part of the route, ie from Betwata and Koi to Kirkuk, and in order to avoid as far as possible risk of engine failure, which meant a certain crash, a system of rigid inspection between each flight was instituted which was successful in preventing forced landings on this part of the route. SM I Wilkinson and Sergt Mallard who carried out this work averaged 16 hours a day for 3 days, in the open, after having originally worked 24 hours shift to get the machines up from Hinaidi.

5. The success, such as it was, of the operation was chiefly due to the following officers:-

Flight Lieutenant Saundby	No 45 Squadron
Flight Lieutenant Hilton.	No 70 Squadron.
Flight Lieutenant Scroggs	No 45 Squadron
Flying Officer Worsley	No 70 Squadron.

6. None of the sick seemed to mind the method of transport, most of them enjoyed it. Serious cases were sent from Kirkuk to Baghdad in the early morning or late afternoon to avoid air sickness during the 'bumpy' part of the day.

7. The whole operation, or a similar one, could be carried out in less than two full flying days if better despatch arrangements were made by the column. With one exception, every machine had to wait from 1 to 4 hours at the column for the load of sick. There seemed to be no adequate reason for this delay, which resulted in employment of an unnecessarily large number of machines and also unnecessarily prolonged the operation.

(Sgd) A T Harris.
Squadron Leader
Royal Air Force
<u>Commanding 45 Squadron.</u>

FLIGHTS MADE, HOURS FLOWN, AND SICK EVACUATED, 45 and 70 SQUADRONS.

Sick Evacuated	198 from Column to Kirkuk 198 from Kirkuk to Baghdad
Machines used	12
Hours flown	128 hours 45 minutes
Mileage	9,615
Forced landings through engine failure with sick on board	1
Forced landings with sick on board due to atmospheric conditions	1
Forced landings without sick on board all causes	2
Crashed without sick on board	1

FLIGHTS MADE	
Hinaidi to Kirkuk	23
Kirkuk to Baghdad	22
Kirkuk to Betwata	11
Betwata to Kirkuk	9
Kirkuk to Koi	15
Koi to Kirkuk	15
Total number of Flights made	95

Exclusive of medical Personnel, two loads of details and two loads of ambulance salvage carried.

BOOK REVIEWS

The Royal Air Force Day by Day by Air Cdre Graham Pitchfork. Sutton; 2008. £35.00.

Because I have to make one or two observations, let me start by saying that I really liked this one and, if I were to nominate a 'Book of the Month', or a 'Book of the Edition', this would be it. *The Royal Air Force Day By Day* has been published to celebrate the RAF's ninety year's of service and it does it by highlighting a random selection of facets of its history, extending the timeframe just a little to embrace the RFC and RNAS. There is no specific 'theme' and the selection of events, people and places that make up the content have been chosen by the author, and there is no one better qualified to have done that than Graham Pitchfork. One can always take issue with a personal selection, of course, and I think that it was stretching a point to claim the Houston-Everest Expedition, Alcock and Brown's transatlantic flight and Andy Green's land speed record, as 'RAF' achievements, but perhaps that's just me.

I found the presentation a little eccentric at first, because, as the title suggests, while the content is arranged chronologically, this is done only by day, not by year. The rationale underpinning this approach is that the book is about 'anniversaries', so the entering argument is a 'birthday' – a specific date. Thus the book opens with a selection of significant 'things' that happened on any 1 January and, within that date, they are listed by year, 1920, 1925, 1927 and so on. It then moves on to 2 January and repeats the cycle throughout the 365 days. The result is a handsome, hefty, 418-page A4 volume. It does take a little getting used to, because, while one might remember, for instance, that the Anson entered service in about 1936, to look it up in this book '1936' is no help at all; you have to know that it was on 6 March. That is where the index comes in; to make the book work, this needed to be really comprehensive, and it is, running to twenty-six two-column pages. So, you can nail that Anson question by entering with the sort of thing that you might already know and 'Anson', 'Manston' or 'No 48 Sqn' will all take you there.

Are there any errors? On a canvas as broad as this, almost inevitably. I spotted a couple of typos, No 685 (for 684) Sqn on p285 and a Leigh-Mallorie (for Mallory) on p354, for instance, and a note on p108 refers us to a map locating Nordhorn Range, but there is no map. I had a problem with one or two ‘facts’. On page 198, for example, it is noted that the 3-inch RP was used for the first time on 2 June 1943, but on p167 we had previously been told that it had already sunk a U-boat on 28 May – I don’t know the answer, but it can’t have been both. The special case of No 51 Sqn aside, the ‘S’ badge continued to be awarded to air signallers until as late as December 1966, not September 1957 as stated on p281. Squadron identification codes are noted as having begun to be applied in September 1937; I suspect that this should have been 1938 (post Munich).

But it is the pictures that make this book really special. I made it about 520 of them, more than one per page, many of them printed full-page width (and less than a dozen printed across the gutter to create that awful staple-in-the-navel effect – why does anyone ever do that?!). They have been drawn from several sources, but notably the AHB collection, and while some may be familiar, many are, I am sure, being seen for the first time. The selection is quite admirable and they have all been chosen to illustrate or amplify specific incidents, locations, personalities, aeroplanes, equipment or artefacts to which reference is made in the accompanying notes. And the notes, which deal with a wide variety of representative topics, are almost as interesting as the pictures.

While you can use this book as a reference work, it is a bit hit and miss because of the random nature of the content. If, on the other hand, you are looking for an appropriate date on which to mount a forthcoming event (or, conversely, need to find an historically significant event to tie in with a date that has already been decided) or are stuck with having to make a speech on a particular day, this book will be invaluable.

The practical implications, aside, however, this book really rewards the casual browser. Every page contains nuggets of information and well-reproduced pictures – and, once you have started, you just keep turning them. If the author’s aim was to evoke and illustrate the particular ethos of the RAF, he succeeded.

It is a bit pricey, but I think worth every penny. Highly recommended.

CGJ

A Passion for Flying – 8000 Hours of RAF Flying by Group Captain Tom Eeles. Pen & Sword; 2008. £19.99

Tom Eeles has written a book which will both delight his contemporaries and paint a vivid picture of life in the Cold War Royal Air Force. This is an enthusiast's account of a career spent very largely in the cockpit, in the course of which the author steered his way around the inevitable postings to ground jobs. At no time did he fail to remain current on at least one aircraft type. The result was over 8,000 flying hours, on 28 military types, achieved in 44 years of uniformed service.

Tom Eeles was an almost exact contemporary of mine, but, unlike me, he can lay claim to the respectability of a proper Cranwell education. His style is light, entertaining and authoritative. He deals methodically with each stage of his training and subsequent flying career, carefully describing the aircraft involved, their operation and characteristics. On more than one occasion, he reminds the reader of the threat of posting to the V-Force that hung over all of us at Valley in the early Gnat days – and later when various subterfuges were employed to avoid that fate. Where Tom's escape route was service with the Fleet Air Arm, my own, more conventionally, was Little Rissington and the CFS course!

The Gnat course of the 1960s was both challenging and stimulating and, almost invariably, followed by a period of 'holding' until a place could be found on one of the front line OCUs. Tom Eeles and I both found ourselves at No 231 OCU, Bassingbourn, each 'entirely content with my fate' and ready for a very gentlemanly introduction to a very gentlemanly aircraft. In reality this was a course almost completely devoid of 'operational' content. Our paths diverged, he going to No 16 Squadron flying the Canberra B(I)8 and the excitements of LABS, while I was bound for the Far East and the recce role. Later, during the Indonesian Confrontation, Fg Off Eeles and No 16 Sqn deployed to Kuantan in West Malaysia, as part of the build up of forces in theatre and he captures nicely the mood of the time and the improvisation involved.

At every stage of this highly readable book, Tom Eeles offers shrewd judgements on the then 'state of the art' and his views on the equipment and capabilities of the Canberra, Buccaneer and other types are typically astute. Who today would argue with his view, for example, that the way in which the shortcomings and deficiencies of the Canberra were overcome were 'not bad training for war – and not a management plan, budget holder, accountant or business consultant in sight'?

At the heart of the Eeles career, of course, lies the mighty Buccaneer and his six tours on that aircraft are fondly and critically described. He deals kindly with those around him, not least with one central figure who has earned mixed notices elsewhere. His assessment of the aircraft, its performance and limitations are highly authoritative. Otherwise, the author's extensive experience in flying training is covered at the gallop and makes good reading.

This 147-page hardback is one of Pen & Sword's better presented books, well illustrated and proof read, with a good index and with only one manuscript caption having escaped the editor's eye. It will delight countless members of Tom Eeles's generation who, had they not known of it before, will put the book down completely convinced of his *Passion for Flying*.

AVM Sandy Hunter

Project Emily – Thor IRBM and the RAF by John Boyes. Tempus; 2006. £17.99

Never envisaged to be more than a short-term system, Thor was intended to bridge the gap between the USSR's imminent ability to threaten NATO (the USA really) until the Americans could field their Atlas rockets, which had the range to strike Russia from the USA. Although the hardware was US-designed and developed, the installations and their operational manning were a wholly British enterprise, the only American participation in the field being the provision of custodians for the warheads and, as with any piece of advanced equipment, a degree of civilian technical support from the manufacturer, the Douglas Aircraft Company. It is quite possible to argue, and there are many who harbour such reservations, some even at the time, that Thor had a number of significant limitations as a weapon system, notably its physical vulnerability (since it was immobile, it could easily have been disabled by a sniper) and its potential lack of responsiveness – while the missiles could, as was repeatedly demonstrated, have been fuelled and launched from a standing start within the specified 15 minutes, how long would it actually have taken to co-ordinate and relay the necessary two-nation political authority required to enable the warhead?

Nevertheless, Thor was at the extreme leading edge of technology in the 1950s and, after a rather uncertain start (there were several spectacularly unsuccessful early test firings) the system was brought to an acceptable level of reliability and accuracy in a remarkably short time and then deployed in the UK. With its 1,500 mile range, it was the first IRBM to be deployed in the west and the RAF was, whether it liked it or not, totally committed to the programme. Perhaps because the Service was never more than half-hearted in its conversion to the gospel of missiles, as preached by its prophet, Duncan Sandys, it does not celebrate the milestone represented by its deployment of Thor to the extent that it should. It was, without question, a major achievement.

John Boyes has set the record straight with his painstaking reconstruction of Project Emily (not to be confused with the, quite separate, Project 'E', which was concerned with the provision of US atomic bombs for delivery by RAF aircraft). He begins his 160-page book (published, a little surprisingly, as a softback) with a summary of the German V2 programme of WW II and traces the post-war evolution of ballistic rockets to the point at which Thor and Jupiter emerged. From then on he focuses on Thor, providing an account of the political negotiations that led to the decision to field the system in the UK, the practical problems involved in siting and deployment, and, once the rockets had been installed, an insight into the daily round of the men who spent five years, 1959-63, tending the sixty launch pads located on, mostly isolated, windswept airfields left over from WW II. All of this is authoritatively presented with the information drawn from both primary sources and interviews with participants, each chapter being underpinned by extensive endnotes. The technical aspects will not tax the layman and a great deal of detailed information is presented in tabular form in appendices, notably: the locations of the twenty Thor squadrons and the dates that each was active; brief details of all significant Thor-related RAF accidents and incidents; and the dates and results of the twenty-one Thors actually launched by RAF crews.

The highlight of Thor's brief military career (it had a much longer and highly successful second lease of life as a satellite launcher) was the Cuban missile crisis of 1962 and its, necessarily low-key, participation in that event is well-covered. Ironically, as Boyes points out, while Thor may not have resolved the Cuban crisis, it may well have caused it, because Khrushchev had probably felt obliged to deploy Russian SS-4s and SS-5s to the Caribbean as a counter to Thor's presence in Europe from 1959, this imbalance being exacerbated by the addition of Jupiter from 1961.

Intrigued by Thor ever since he first saw one way back in 1959, Boyes has spent the last fifteen years or so delving into its background and he presents his findings in a cogent and, in view of his acknowledged affinity for his subject, an admirably impartial fashion. Thor did have some warts, and he makes no attempt to hide them. This tale has waited a long time to be told. Now it has been, and it has been told well.

CGJ

Bletchley Park Air Section – Signals Intelligence support to RAF Bomber Command 1943-45 by John Stubbington; 2007. Available from the author (at £17.00 inc P&P; cheques payable to John Stubbington) at Trinity Hill Bungalow, Trinity Hill, Medstead, Alton, GU34 5LT.

I enjoyed reading this book, which provides a most interesting insight into the operational contribution made by the Government Codes and Ciphers School (Bletchley Park) and the RAF Y-Service to Bomber Command and the Combined Bombing Offensive. Its logical build up of the capabilities of the British, American and German air forces and their use of signals intelligence material leads to a succinct review of the Combined Bomber Offensive.

The author highlights the difficulty posed by the security constraints associated with ULTRA data derived from the decoding of ENIGMA intercepts. At the same time he outlines the major contribution made by the RAF Y-Service intercepts to Order of Battle information and the understanding of the German Air Force's air defence system and tactics. It required the initiative of a small number of dedicated individuals to ensure that information contained in ULTRA and Y-Service reports was fused to provide a more rounded and, eventually, more timely intelligence report to be delivered to operational commanders. Air Intelligence within the Air Ministry was unresponsive and often obstructive.

The contribution made with Radio Countermeasures and Mosquito Intruders by No 100 (Bomber Support) Group to the overall bombing campaign was immense and was claimed to have saved 1,000 bomber aircraft and their crews. The book shows how RAF Y-Service intercept material was used to develop both jamming and intercept equipment and tactics. The introduction of WINDOW enabled spoofing operations to be conducted with each bomber raid to dilute the effectiveness of the German Air Defence. The use of the 'Kingsdown Hook-Up' provided immediate Y-Service intelligence, from intercepts of German radio traffic, to be immediately combined with ULTRA background material, which permitted bomber routings and tactics to be altered and enhanced the effectiveness of the jamming/spoofing during the raids.

One of the conundrums of the bombing campaign was the use of ULTRA material. Sir Arthur Harris was not authorised to have direct access to ULTRA; his Command Intelligence Officer was able to make limited use of ULTRA material in 1943 and was fully briefed into ULTRA in 1944. The 8th United States Army Air Force did not have a similar constraint and it forged a close relationship with Bletchley Park, using both ULTRA and RAF Y-Service intercept material to plan its raids and to support its escort fighters over Germany. This difference in ULTRA dissemination was in conflict with the principle of 'linked routing' that was intended to serve two or more Commands operating jointly. The author highlights the problems of target selection during the Combined Bomber Offensive and the use of ULTRA material and photo reconnaissance pictures to assess raid effectiveness.

In my view the author has captured the essence of the contribution of Bletchley Park and the RAF Y-Service to bombing operations when he states: 'The nature and scale of Signals Intelligence and Radio Countermeasures within the Combined Bombing Offensive were at the leading edge of the then current technologies and their operational applications. There were outstanding successes which contributed substantially to the conduct of the Combined Bombing Offensive.'

In today's world of Network Centric Warfare and with the ever-increasing number of intelligence-gathering sensors the lessons learnt from the contribution of intelligence to the bombing campaign are still pertinent:

a. Timely data fusion and dissemination.
b. Understanding the operational users' needs.
c. Preventing security constraints impacting on the delivery of intelligence reports to operational commanders.

AVM John Main

The Royal Air Force – An Encyclopaedia of the Inter-War Years, Volume II – Re-armament 1930 to 1939 by Wing Commander Ian M Philpott. Pen & Sword; 2008. £35.00.

My review of Volume I of this ambitious work of reference was, at best, grudging and heavily qualified. I therefore approached the task of reviewing this second (544-page hardback) volume intent on bending over backwards to discern the good in what is clearly a labour of love and to give credit to the author's energy and perseverance. I fear that these worthy aims have not entirely led me to modify much of my earlier criticism of this *magnum opus*. However, what does become ever-clearer is that the author's effort is matched in neither volume by the quality of the editing of this undeniably expensive series.

The scope of Volume II is of great interest, given that it covers the period of belated expansion that saw the Royal Air Force into war. Wing Commander Philpott's approach is very similar to that in the earlier volume. In compiling this compendium he has relied heavily on secondary sources, some acknowledged and others unacknowledged, but recognisable. The Bibliography is short and reflects the extent to which this latest volume has depended on the work of others, our own Editor's included. The author's Foreword offers a justification for the inclusion of 'photographs or images of aircraft so often in among the narrative', where none is really necessary. By contrast, his reasoning for the omission of footnotes is unconvincing and one suspects that the real reason may have been one of economy on the part of the publishers.

It is, perhaps most of all, the failures of editing that cast doubt on the value of this work for the student of Royal Air Force history. Just as in Volume I, the quality of reproduction of some photographs is poor and the maps lack any semblance of consistency or coherence. Many of the diagrams would sit more naturally in the pages of *The*

Wonder Book of the RAF, of fond memory, than in what sets out to be a major work of reference. Minor errors and uncorrected misspellings may irritate the reader and raise questions for him. In short, what may be viewed as failures of proper editing detracts substantially from the work. Fortunately, the Index is perfectly adequate, for there are some nuggets buried away in the text.

So what is there to commend this volume to the amateur historian? The answer, perhaps surprisingly given my criticisms, is that there is much of interest between its covers. In particular, Wg Cdr Philpott's account of the expansion period in terms of personnel and training policies and of the provision of real estate are well put together and offer a glimpse of problems largely overshadowed in other accounts by the inevitable focus on aircraft development. His reproduction of many Air Ministry Orders, although sometimes descending into very obscure detail, does illustrate the mood music of the times. Similarly, the many pages of squadron diary material do paint a picture of contemporary operations in areas that are, once again, familiar to the Royal Air Force.

So, to buy or not to buy? I imagine that I will not be the only Scot who will find the £70.00 cost of the two volumes excessive and to prefer to access the volumes through a library service – but access them I undoubtedly will.

AVM Sandy Hunter

Squadron Leader Tommy Broom DFC** by Tom Parry Evans. Pen and Sword; 2008. £19.99.

In case the very specific title of this biography fails to ring any bells, Tommy Broom was a regular airman who enlisted in the RAF in 1932. His first posting was to No 40 Sqn at Abingdon as an ACHGD but he soon acquired a trade, as an armourer, serving with the CFS at Upavon until 1936 when he was posted overseas to spend the next two years with Nos 47 and 6 Sqns. Returning to the UK in 1938, he trained as an observer, qualifying in January 1939 just in time to become one of the very first of a new generation of sergeant aircrew. He subsequently flew Battles (in France), Blenheims and, after a stint with No 13 OTU, Mosquitos with No 105 Sqn. Following a crash-landing in Belgium, as a result of hitting an electricity pylon in August 1942, he was back in the UK by October, having been repatriated via

Spain and Gibraltar by the *Comète* Line. He spent the next eighteen months on the staff of No 1655 Mosquito Training Unit before crewing up with his namesake, Flt Lt Ivor Broom, and returning to operational flying in May 1944. The two Brooms flew together in the Pathfinder Force for the rest of the war, initially with Nos 571 and 128 Sqns and, from January 1945, with No 163 Sqn which Ivor, by now a wing commander, commanded with Tommy as his squadron leader Nav Leader. In all Tommy Broom logged 83 operational sorties, 58 of them flown with Ivor. After the war Ivor stayed in uniform, eventually becoming Air Marshal Sir Ivor, but Tommy had left before the end of 1945. He joined the Control Commission in Germany in 1946 and returned to the UK in 1949 with a wife and stepdaughter. The family settled in Somerset where Tommy spent the rest of his working life in clerical appointments with firms in Avonmouth and Bristol.

So much for the story. What of the book? In view of its sub-title, 'The Legendary Pathfinder Mosquito Navigator', and the exciting tale that one anticipates, it reads rather oddly at times and I was a little bemused to find that the first few pages were all about the history of Portishead (a revelation to me – it's a place, not a band!) and the Gordano Valley, stretching right back to the Bronze Age. I seemed to be reading a local book for local people and, on closer examination, it turns out that that is exactly what it is. It was originally published in 1999 as 'A Posset Lad' (Posset being *patois* for Portishead – Broom's home town). Presumably for the benefit of the original readership, the narrative tends to keep returning to Portishead and, for those (like myself) with no interest in these parochial interludes, these diversions may represent a distraction.

There are some other, essentially didactic, passages that are somewhat tangential to a biography of Tommy Broom, including a list of the territories that constituted the pre-war British Empire and a three-page diversion on the assassination of Heydrich and the atrocities of Lidice and Oradour-sur-Glane. Much of Chapter 11 is devoted to the aids and techniques used by the pathfinders but the relevance of this is also questionable, as Tommy flew with the Light Night Striking Force which, while it was subordinate to HQ 8 Gp, was not actually in the target-marking business. There are one or two minor errors: eg the PRU was in Coastal, not Bomber, Command (p76); He 117 should read He 177 (p113); the standard post-1942 bomb sight was the Mk XIV (not XVI – p128) and, more significantly, the German offensive in the Ardennes began in December 1944, not 1943 (p107).

These reservations aside, the book, which is a 192-page hardback with an index and a photographic insert, is well-written. I had no issues with the syntax and it is refreshingly free from typo blight. It does succeed in doing what the author set out to do, which was to provide an account of Broom's life; 90% of the content is devoted to his time in the RAF, and it is good to have the story of a navigator told for a change. I think that, before being relaunched as an aviation title, this one might have benefited from having had its text revised by an aviation writer. Nevertheless, Broom's war was certainly eventful enough to sustain one's interest and his story provides a good read.
CGJ

Turbojet History and Development 1930-1960, Volumes 1 and 2 by Antony L Kay. The Crowood Press; 2007. £40 each.

Let me say from the outset that these are beautiful books. The quality of paper, illustrations and layout took my breath away when I first held them and if any volumes deserves the term 'coffee table books', these are they. But they are far more than vanity productions. Tony Kay has an engineering and technical background and he has for many years run his own optical instrument business. These two volumes are obviously a labour of love as he traces the development of the turbojet, turboprop and turboshaft engine in twelve nations (the UK, Germany, the USSR, USA, Japan, France, Canada, Sweden, Switzerland, Italy, Czechoslovakia and Hungary) from the earliest days right up to the end of the 1950s.

Volume 1 sets out to tell the full story of early jet development in the UK and Germany. The engines are described in full detail together with the aircraft they powered. The cutaway diagrams are very good but as I am not a 'sooty', I went straight to an aircraft I know very well, the Avro Vulcan. The author told me that the range of my Vulcan B2 powered by 200-series engines was 4,600 miles, which was so far out that I would have had to pedal for over 1,000 miles. He also told me that I carried conventional bombs after Polaris took over the British strategic nuclear deterrent, which made me wonder what that white shape was in the bomb-bay. On the next page there was reference to ‘Bristol’s’ Orpheus engine. Pity about the little inaccuracies!

There is some very good historical material in these books, whether it be about the Miles M.52 supersonic aircraft project that never was or the Mach 2 stainless steel Bristol Type 188. This is a great book for dipping into but the trouble with going for width across twelve countries, and trying to cover every engine, is that you miss out on depth. Under the Sapphire turbojets section there is quite a bit of material on the Victor that has long been in the public domain but nothing about turbine centre-line closure which was potentially fatal to Victor B1s and Javelins out East.

Kay is very good on engine technicalities but not so good on personalities and politics. Towering jet engineers such as Frank Whittle and Stanley Hooker don’t come alive in this book, which is a great pity because the history of turbojets is as much about personalities and egos and politics as it is about slide rules. ‘Following this lack of interest, Whittle did not give up on developing his turbojet ideas and in his spare time he conceived many new schemes.’ Yawn – I wish Kay could have been more enthusiastic. There are so many controversies surrounding early turbojet development – was Whittle denied the support he deserved in the early days by a purblind Air Ministry? Did the Germans steal a march on getting the first operational jet aircraft into the air? Moreover there is much that has come to light in recent years to help answer such questions authoritatively. Anthony Furse’s excellent biography of Sir Wilfrid Freeman showed that Freeman and Tedder had recognised the potential of Whittle’s ideas on ‘jet propulsion’ as early as 1936, and supported his proposal that Power Jets should cease to work with BTH and team up with the Rover car company rather than an established aero-engine manufacturer. Given that, just before the Munich crisis in 1938, the Rolls-Royce aero-engine factory at Derby, even working at maximum capacity, could turn out a mere thirty Merlins a week, this may have been wise advice. What does Kay say on the matter? Very little.

Then again, the Society heard a stirring plea from Ian Whittle in 2006 for British aviation historians to counter what he saw as the US-inspired myth that Dr Hans von Ohain invented the turbojet, relegating ‘early British turbojet development to a state of irrelevance’. What contribution does Kay make to this debate? Nothing.

Then I turned to the entry for the He 162 *Volksjäger*, a remarkable last throw of the dice in late 1944. That doyen of UK test pilots, Eric 'Winkle' Brown, describes it as having the finest controls of any aircraft he had ever flown and he says that 'a more powerful jet and a swept back wing might have made it a phenomenal machine'. An abiding question for the Second World War is not 'how did the Germans make so many dodgy decisions about aircraft procurement?' but rather 'how did they come up with so many potentially world-beating jet aircraft, even as Bomber Command and the USAAF were blowing the roof off the Reich?' Kay doesn't seem to have interviewed any survivors on these or any other issues, which is a great pity.

In sum, these beautiful books turned out to be a bit of a let-down. The pair are for taking into ground school jet engine lessons or, if you need a first rate aero-engine compendium, but they do not come cheap. Unfortunately, for me, there is too little human or political drama within, which is a pity because early turbojet development is a powerful and dramatic subject.

Wg Cdr Andrew Brookes

UPDATE

Members may recall from Journal 42 that, in reviewing Volume 9 (Roll of Honour), the last of W R Chorley's *Bomber Command Losses of the Second World War*, I sounded a note of caution. Because amendments and additions have been published in the series over some fifteen years, you would need access to the whole set to be confident that you were fully up to date with all the many changes. Since Vol 9 is the last in the series, it also looked as if there would be no further updates. These issues have been addressed by RAFHS member Frank Haslam. Working with Bill Chorley and with the sanction of the publishers, he has built a website which consolidates all published and unpublished changes to date. The website should attract new information, which Bill will review, before it is added to the database; any input would be welcome. The url is http://www.rafinfo.org.uk/BCWW2Losses/ **Ed**

FEEDBACK

The Journal 42 article on aircrew status in the 1940s stimulated more than the usual amount of interest and several members were moved to write to the Editor. Peter Mills' contribution is representative. He first saw an example of the new-style aircrew badges when he was undergoing his basic training at Cardington in 1947. He writes: 'I questioned the wearer, an Aircrew II, and he was extremely critical and dismissive of the new badges. As a matter of interest, his badges were of a printed variety and not embroidered in silk.' Peter goes on to note that, 'I picked up an Aircrew III badge in mint condition at a car boot sale some years ago and recently sold it on ebay for £75.'

So it would seem that some good came of the scheme after all. **Ed**

ERRATUM

The eagle-eyed may have spotted an error in my caption to the photograph on page 80 of Journal 42. It says that the airmen are four P2s and an N2. If you look closely, you can see that only the two pilots nearest the camera are P2s. The other two and the nav are P1s and an N1 (their badges are surmounted by crowns). **Ed**

ROYAL AIR FORCE HISTORICAL SOCIETY

The Royal Air Force has been in existence for over 80 years; the study of its history is deepening, and continues to be the subject of published works of consequence. Fresh attention is being given to the strategic assumptions under which military air power was first created and which largely determined policy and operations in both World Wars, the inter-war period, and in the era of Cold War tension. Material dealing with post-war history is now becoming available under the 30-year rule. These studies are important to academic historians and to the present and future members of the RAF.

The RAF Historical Society was formed in 1986 to provide a focus for interest in the history of the RAF. It does so by providing a setting for lectures and seminars in which those interested in the history of the Service have the opportunity to meet those who participated in the evolution and implementation of policy. The Society believes that these events make an important contribution to the permanent record.

The Society normally holds three lectures or seminars a year in London, with occasional events in other parts of the country. Transcripts of lectures and seminars are published in the Journal of the RAF Historical Society, which is distributed free of charge to members. Individual membership is open to all with an interest in RAF history, whether or not they were in the Service. Although the Society has the approval of the Air Force Board, it is entirely self-financing.

Membership of the Society costs £18 per annum and further details may be obtained from the Membership Secretary, Dr Jack Dunham, Silverhill House, Coombe, Wotton-under-Edge, Gloucestershire. GLI2 7ND. (Tel 01453-843362)

THE TWO AIR FORCES AWARD

In 1996 the Royal Air Force Historical Society established, in collaboration with its American sister organisation, the Air Force Historical Foundation, the *Two Air Forces Award*, which was to be presented annually on each side of the Atlantic in recognition of outstanding academic work by a serving officer or airman. The RAF winners have been:

1996	Sqn Ldr P C Emmett PhD MSc BSc CEng MIEE
1997	Wg Cdr M P Brzezicki MPhil MIL
1998	Wg Cdr P J Daybell MBE MA BA
1999	Sqn Ldr S P Harpum MSc BSc MILT
2000	Sqn Ldr A W Riches MA
2001	Sqn Ldr C H Goss MA
2002	Sqn Ldr S I Richards BSc
2003	Wg Cdr T M Webster MB BS MRCGP MRAeS
2004	Sqn Ldr S Gardner MA MPhil
2005	Wg Cdr S D Ellard MSc BSc CEng MRAeS MBCS
2007	Wg Cdr H Smyth DFC

THE AIR LEAGUE GOLD MEDAL

On 11 February 1998 the Air League presented the Royal Air Force Historical Society with a Gold Medal in recognition of the Society's achievements in recording aspects of the evolution of British air power and thus realising one of the aims of the League. The Executive Committee decided that the medal should be awarded periodically to a nominal holder (it actually resides at the Royal Air Force Club, where it is on display) who was to be an individual who had made a particularly significant contribution to the conduct of the Society's affairs. Holders to date have been:

Air Marshal Sir Frederick Sowrey KCB CBE AFC
Air Commodore H A Probert MBE MA

SECRETARY

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MEMBERSHIP SECRETARY
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