



CLEAR AIR TURBULENCE

A Life of Anne Burns

Matthew Freudenberg

To Wally,
with best wishes,

Matthew

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Dedicated to my wife, Wendy; above all for her support and interest in this project, in spite of the anti-social aspects of publishing from home; secondly for her help unravelling Anne's character; and thirdly for her usual incisive proof reading.

Published in 2009 by Charlton Publications
Orchard House, Creech St Michael, Taunton TA3 5PF

Other publications by this author.

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ISBN 0-9546165-3-7

Printed in Somerset, England by Acanthus Press Ltd.
www.acanthuspress.ltd.uk

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Back Cover Image: The Northern Polar Jet Stream crossing Cape Breton Island, Canada. The Jet Stream is a narrow zone of high-speed winds typically found at 4 to 8 miles above the earth. They result from temperature contrasts between polar and tropical regions. *NASA satellite photo*

ACKNOWLEDGEMENTS

I am indebted to Anne's brothers Myles and Tim Pellew for recollections of their sister reaching back to childhood, and to her nephews Nick and Philip for affectionate memories of an interesting aunt. Their loan of Anne's flight log books and family archives has also been extremely helpful.

My thanks to Captain Eric Brown RN, senior test pilot of the Royal Aircraft Establishment Aero Flight, with whom Anne flew as an observer, and played a high standard of tennis, for much information about test flying at the RAE, and about aircraft of bad character. Thanks also to Brian Kervell for describing the organisation and events at Farnborough during his service in several capacities there, ending as Librarian of the Establishment.

Wally Kahn, prime mover of Lasham Gliding Club, knew and supported Anne from the time she started gliding. Judith and Brian Slade were gliding crew members for both Wally and, later, Anne. I have learned much from the three of them about Anne and about competition gliding. Thanks also to Susan Newby, Editor of "Sailplane and Gliding" magazine, for permission to use pictures and the report on the 1966 British National Gliding Championships from "Sailplane and Gliding." For information about a very different kind of gliding I am indebted to the Museum of Army Flying at Nether Wallop, and particularly to Keith Male, who provided details of wartime trials of "snatching" troop-carrying gliders, in which Anne took part as an observer.

For his tireless work in seeking out Anne's technical reports in the Farnborough Air Sciences Trust archives, as well as more social items in the RAE News of her time at the RAE, I cannot thank Alan Brown of FASTA enough. He and his colleagues at the FASTA museum also helped to reduce the mass of material on the Comet jet airliner crash investigations to manageable proportions.

The help given by Alex Morrice, meteorologist, in guiding me past the pitfalls of Clear Air Turbulence is much appreciated. Where Anne recorded the phenomena of these forces in algebraic formulae, Alec can find clear illuminating words. Lawrence Voller's descriptions of the visit of the RAE/Met Canberra, for which he was instrument engineer, to south Australia to seek turbulence near the sub-tropical jet stream, gives an interesting view of the organisation of such investigations.

I must thank Philip Jarrett, aviation historian, for offering from his formidable collection the loan of excellent pictures of aircraft relevant to Anne Burn's career. The offer was gratefully accepted and these pictures are identified in their captions.

A PERFECT DAY

May 27, 1965.

It was a perfect day.

The National Storms Laboratory at Norman, Oklahoma, reported severe storms developing about 100 miles southwest of the city in the early afternoon. By the late afternoon, as a Canberra B6 piloted by S.G.Corps, with Anne Burns, Royal Aircraft Establishment, and a scientist from the National Severe Storms Laboratory of Oklahoma as observers, was climbing to 40,000 to 45,000 ft., the storms were described as “well developed”, and a tornado had been reported. Later there were reports of two more tornados and “baseball-sized” hail.

Anne was looking for just these conditions and directed the pilot to aim between two massive storm tops, one towering to 46,000ft and one decaying to 43,000ft. Flying in the ravine between the storm tops the Canberra hit moderate turbulence, which produced a gain in speed of the aircraft of about .04 Mach. with no adjustment of engine speed. The two observers watched the decaying cloud folding in from outside to the centre and descending toward the cloud base, the point at which a tornado would touch the ground.

Anne’s report takes up the account: “At this stage, ground control reported a tornado from the southern edge of the cloud, so a pass was made along the southern edge toward the reported tornado. The aircraft was now heading southwest through some very thin cirrus at 45,000 ft. and out toward clear air between two Cb (cumulonimbus) heads at about 0.74 Mach, (about 500mph at this altitude.)

“Quite unexpectedly severe turbulence was entered, which continued for 2 minutes; after 1 minute the aircraft was gaining in speed and height. As the aircraft left the disturbance, speed increased rapidly without any apparent change in pitch angle or significant change in height. Indicated Mach number increased from 0.74 to 0.84 and the aircraft got deep into high Mach buffet - rocking from fore to aft. The speed increase took place in about 20 seconds and a few hundred feet of height were lost.

“I had been convinced that the aircraft was headed toward smooth air before this area of disturbance was reached, and I could well imagine a civil captain calling “in the clear” before all this started.”

The Canberra was instrumented to measure gusts, aircraft response and other meteorological conditions, and cine cameras were fitted to monitor the pilot’s control movements and scan the more promising-looking clouds around. The flight was tracked by radar from the National Severe Storms Laboratory.

Anne had found the Clear Air Turbulence that she was looking for; severe enough to subject the pilot in the nose of the Canberra to pitching and “flexural oscillation” just as he was trying to stabilise his airspeed against acceleration caused by horizontal gusts. In her report on the 135 minute flight, she stated that she considered that the pilot of a larger, less responsive commercial aircraft could have difficulty in handling the same rapid combination of horizontal and vertical gusts quickly enough to prevent a build up of uncontrollable oscillation.

The purpose of the flight was to analyse and classify the disturbances experienced, adding to data which would be used to improve

the forecasting of Clear Air Turbulence for pilots. This invisible force had been the cause of numerous flight incidents on passenger and other aircraft, with effects ranging from the sudden stomach churning, but harmless, momentary loss of height familiar

to most frequent flyers, to major damage to aircraft and death or severe injuries to passengers. Turbulence, but above all, Clear Air Turbulence, was Anne's favourite environment.

FARNBOROUGH.

Early in 1940 Anne Pellew started work at the Royal Aircraft Establishment at Farnborough.

Research at Farnborough was not Anne's first choice of career; she had hoped to fly with the Air Transport Auxiliary, not knowing that a pilot's licence was the first requirement for acceptance by the ATA: she had no flying experience. However, at twenty - four, she was very well qualified for the RAE, having a 1st Class degree in Engineering Sciences from Oxford University, and post-graduate research experience assisting Professor Richard Southwell with work in engineering-related mathematics - "Relaxation Studies".

The Farnborough Establishment of 1940 was a huge complex of centres of scientific research and technical development. There were thirteen major Departments, from Aerodynamics and Engine Experimental to Camouflage and Structural Engineering. These were served by production and repair "shops" - foundries, metal workshops of all types, instrument and machine shops and many others, as well as a large drawing office, inspection department and about six service departments including a medical department and medical officer. There was an Accounts and Employment Department, whose title gave a fair indication of the place of staff welfare in the Establishment's priorities. Pay, promotion and holidays were governed by a highly complex set of grades and rules, and individual queries about the correctness of salary levels seemed to be answered by "fresh-minted" sets of rules. On the South side of the complex, a sizeable airfield accommodated the Experimental Flying Department: their sheds and hangars were the operational bases of Aerodynamics Flight and Flights specific to Engine Department, Mechanical and Electrical Engineering, and High Speed and

High Altitude Test Flying.

The physical separation of Departments, and usually of the sections within departments, did not promote informal friendship between staff at Farnborough and they were further distanced by the importance given to rank in the system. In the research departments, one started as a Scientific Assistant 111 and hoped to work one's way up, through the years, by way of Scientific Assistant 11, Scientific Assistant 1, Technical Officer, Principal Scientific Officer to Senior Principal Scientific Officer. Even at this lofty rank one would be expected to stand in the presence of a Director or Deputy Director: at any address to the rank and file by one of these important men, the audience would be called to attention by a member of the RAE Constabulary. It was not normal for senior ranks to chat to lower ranks.

Having said all this, the Establishment's Directors and Heads of Departments were not all ogres. W.S.Farren and W.G.A. Perring were two Directors who spoke to subordinates and made efforts to reduce prejudice between the sexes. Their efforts did little to change many men's view that women were intended for clerical work, and women's view that many of the men were barely fit to do their job.

Anne's familiarity with maths probably made her feel more comfortable than many new recruits in the complex environment of the Royal Aircraft Establishment. At the RAE, Maths was the language of the stresses, accelerations and decelerations, and forces affecting aircraft behavior in flight.. ("Relaxation" maths is the study of stresses and safe loads in a structure where load bearing support can be varied.)

She was assigned to Structural and Mechanical Engineering Department, specifically to Structural Research (Experimental), one of the twenty - two sections in the Department



Aerial view of the Royal Aircraft Establishment in the mid 1960s, showing the runways and aircraft hangars of Experimental Flying Department and other Flights to the upper left, (South), of the Establishment. *DERA photo*

at that time, which ranged from Accident Investigation to Hydraulics (General.) Most sections had fifteen or more members, including a Principal Scientific Officer or Principal Technical Officer as leader. Staff were given the minimum information necessary to allow them to carry out their task and forbidden to discuss work with anyone outside their section.

Anne was less likely to be affected by the sheer size and limited social contacts that might have worried other newcomers to the RAE. Her concentration on work in hand

was absolute, and she was not interested in small talk. She was quite happy to be the only woman in a section of nineteen, and in Structures she found a like mind in George Naylor, another honours graduate in Engineering with a gift for mathematics. George had joined Structures, or Mechanical Test Department as it was then called in 1937, and was familiar with the structural problems, investigation methods and terms that were the essence of their work.

The most commonly used term was “flutter”, defined by Anne Burns as “unstable

oscillations of control surfaces of an aircraft". If this happened in flight it could develop from flutter to severe pitching - or to damage to or complete loss of a control surface-rudder, aileron or flap - and complete loss of control. Those who worked in this department were known by some staff as "flutter-narks;" women like Anne were sometimes described as "boffinettes".

Anne taught George some of her advanced mathematics, while he introduced her to some of the most common structural problems. In April 1942 they co-wrote a report on "Binary Aileron and spring Tab Flutter". George wrote a "note" entitled "An Approximation simplifying Wing Flutter calculations" in the same year, before leaving the RAE to train and serve as a pilot in Bomber Command.

Although "flutter" was perhaps the most common problem investigated by Structures and Mechanical Engineering, failure of aircraft parts to support their design load was also common. Collapse of an aircraft in flight was a common and usually fatal occurrence in the pioneering days of powered flight. Between 1908 and 1913 the American-born, self-taught constructor of powered gliders, Samuel Cowdery, built a series of light biplanes in the Army Balloon Factory at Farnborough, the forerunner of the Royal Aircraft Establishment. He was a major inspiration of powered flight for military purposes, but in August 1913 he and his passenger were killed when his biplane "doubled up in the centre" at 250 feet, throwing them to the ground.

Anne was deeply involved in testing aircraft strength, which remained a critical subject long after the age of fabric, wood and tension wires. The RAE moved toward the testing of new military designs to destruction, with scientific measurement of the maximum loads the wings, main frames and tail components could withstand, compared to the loads the aircraft designers believed they had built into their product. In his history of the RAE, Peter Cooper illustrates the importance of destruction testing of new designs with the example of the Short Singapore Mk II, whose main spar frame collapsed under a test weight

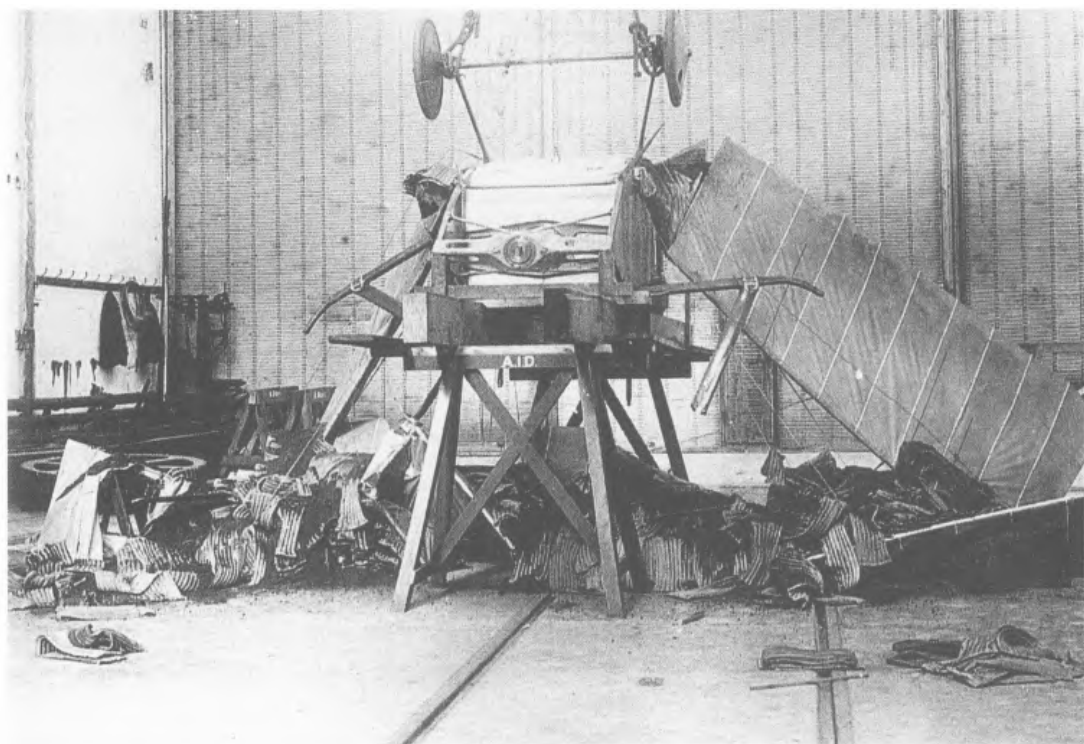
of 3,000lb., "somewhat short of its design load of 10,000 lb." under test in 1930.

The apparatus used for these static tests were massive test frames designed to surround a wing, or a fuselage, or finally the complete aircraft. From this framework powerful hydraulic rams were attached to points on the wing or aircraft under test, and these rams rose and descended to a preset programme, their force rising up to and beyond the design strength of the component being tested - until it "failed" - (this being the polite word for "broke".) The movement and power exerted by the rams, and the amount of movement of the tested components were continuously measured and recorded throughout the test. Anne and her colleagues analysed and translated the test figures to give a clear though inevitably mathematical account of damage sustained and conclusions to be drawn.

The large test frame used on the Short Singapore was named "The Temple". The even larger "Cathedral" and "Abbey" followed in 1938 and 1946, as testing to destruction became a required procedure for new designs, and the number of designs multiplied.

Every bit as important as static structural testing was test flying of new or suspect aircraft. The manufacturers of the new fighter aircraft that were introduced during the rearmament period prewar, then through the war itself, were all flown first by test pilots employed by the manufacturers. These men of extraordinary skill and courage developed a fine sensitivity to potential trouble that enabled them to fly their aircraft as no one else would dare to. Farnborough also had test pilots, with the same qualities, seconded from the RAF and the Navy.

At Farnborough, pilots flying aircraft with the object of identifying the cause of instability, poor response or, distressingly often, of unexplained fatal accidents, would fly with a Flight Test Observer - as long as the aircraft was not a single seater. The FTO would arrange the instrumentation of the machine



Early load testing. A Sopwith Tabloid with wings loaded to destruction with bags of lead shot in 1914. *DERA photo*



The scene of Cowdery's fatal crash on August 7th, 1913. The aircraft collapsed in mid air at 250 ft due to lack of structural strength. *DERA photo*



A flight of Hawker Hurricanes, the most effective British aircraft in the Battle of France

Philip Jarrett collection

to be test flown with the person in charge of the Department's Test Flight. In the case of Structures Department this was one of the several women scientists whose contributions to Farnborough's achievements were barely acknowledged, Helen Grimshaw.

Captain Eric Brown RN, senior pilot of Aerodynamics Flight, who also test flew for Structures and Mechanical Engineering, remembers Helen Grimshaw as "a kind and sociable person." She was a specialist in troop-carrying glider development, and in 1942 wrote the RAE manual for safe procedure in glider flying trials.

It is probable that by the end of 1940 Anne was getting frustrated at being restricted to work on the ground, and Helen would have been sympathetic to her eagerness to fly. Anne's work load was already considerable, and had recently included attacking the problem of ice formation on bomber windscreens in foul weather and at high altitudes as well as the usual flutter and structural strength problems.

A solution was found by diverting heat from the exhaust system to the base of the screen.

In January 1941 Anne was appointed a Flight Test Observer - and her wish to carry research into the air was fulfilled. There were plenty of combat aircraft with bad habits that could and did kill aircrew. The Fairey Battle could lose power in the climb and stall if the pilot was unaware of its badly designed throttle control; the Lockheed Hudson reconnaissance bomber, bought in quantity from the United States in 1939 was highly regarded by Coastal Command for its performance as a submarine chaser and enemy battleship hunter. Its popularity dipped when over fifty incidents of Hudsons going straight down under water after being forced down in combat over the sea caused a heavy loss of aircrews. The fault was found to be bursting open of the bomb doors and bomb aimer's window due to their lack of strength, and was cured by strengthening these components. There were many others with serious shortcomings which were discovered by flight testing, and were



A Fairey Battle shot down in German occupied France. One hopes the crew survived as well as the aircraft. *Philip Jarrett collection*

subjected to re-design.

Anne flew as FTO on tests of such aircraft, and also on strenuous tests of aircraft which had flown without major incidents but could be subjected to violent forces in evasive manoeuvres, such as the “corkscrew” twisting and diving used by bomber pilots to avoid a following enemy fighter, or to the strains of heavy bomb loads. She was absorbed by her work, and pleased to be involved in flight testing. Most of the staff at Farnborough, regardless of rank, understood in 1940 that Britain faced an enemy far stronger than herself, and that their work was vital to changing the balance of power.

A short summary of events in Europe and Scandinavia between the declaration of war with Germany (September 1939) and the middle of 1940 might give some idea of the desperate situation of Great Britain at the end of this period.

At the beginning of 1940, most of the work at Farnborough was a continuation of prewar projects. A high speed wind tunnel was under construction to allow large (6ft span) model aircraft to be tested at speeds up to 600mph, under pressures up to four atmospheres; Aerodynamic Department was quantifying different types of instability in flight to enable mathematical calculations to guide physical tests, and Engine Department was seeking to prevent carburettor icing and develop an injection carburettor which would give constant fuel flow in all conditions of temperature, pressure and aerobatic flight.

These studies were still fully relevant to combat flight after war was declared in 1939, but a host of problems experienced with aircraft which had been accepted for service by the Ministry of Air Production were now demanding immediate attention to prevent further aircrew losses in the fighting that was swiftly gaining momentum in France.

Germany invaded Poland early in September 1939, and on Germany's refusal to withdraw, France and Britain declared war. Germany quickly moved troops up to the French border, and in mid October the British Expeditionary Force landed in France to help to turn back the invaders. The German attack was swift and well planned. The French and British were surprised by speed of the German advance, and their attempts to hold it back were handicapped by poor communications at both command level and at the front line.

The British Air Forces in France, consisting mainly of four Squadrons of Hurricanes, two of Gloster Gladiators and an "Air Striking Force" of Battle and Blenheim bombers, were positioned at airfields roughly between Le Havre and the Belgian border. Their first days in France were occupied with intensive training in formations, tactics and communication to prepare recently - trained pilots for their first encounters with hostile aircraft. These came quickly enough, and although many German bombers were shot down, the seemingly countless Messerschmitt 109s, 111s and Heinkel bombers outnumbered and outgunned all but the Hurricanes of the British. The French Air Force were capable, daring and helpful toward British airmen. Unfortunately they were equipped with Morane 406 fighters powered with Hispano-Suiza engines giving less than half the power of the Mercedes-Benz engines of German fighters, and over 400 were shot down by the enemy.

A freezing, snowy winter slowed down operations in France between November and mid February, but in Spring 1940 German attacks intensified with a drive that forced the B.A.F.F. squadrons to retreat Westward toward Rheims, suffering heavy losses. Many British pilots were demoralised, if not in shock, from seeing the masses of civilian refugees, also going West, being subjected to

murderous Luftwaffe attacks on the roads - attacks which they were powerless to prevent. Finally, the remains of both the British Expeditionary Force and of the B.A.F.F. left France either from Dunkirk in the first days of June 1940, or in their aircraft soon after. A good number of French troops and airmen were able to escape with them to continue the fight.

While the Battle of France was under way, Germany invaded and forced the surrender of four further countries: Denmark, Norway, Belgium and Holland. After the surrender of France on June 22 1940 and the German occupation of the Channel Islands on July 1, eleven days later, there was little doubt in most people's mind as to which was the next country to be invaded and occupied by Germany.

Fortunately Germany had neither the confidence nor the means to invade Britain while she was recovering from the Battle of France. Hitler and his Chiefs of Staff required the destruction of the fighting capacity of the Royal Navy and the Royal Airforce before launching an invasion, but the German Navy lacked the fighting ships to control the Channel or the Channel ports. Many had been lost in action on the Norwegian coast and the North Sea.

The pre-invasion "softening up" was put in the hands of the Luftwaffe, who were still strong and probably outnumbered the RAF. The Battle of Britain was fought and decided in the air, according to postwar history, between mid-August and mid September 1940, and although the Navy and coastal defences made invasion impossible for the Germans, the courage and determination of the men of Fighter Command forced Hitler to abandon his plan after little more than five weeks.

Three

THE FAMILY BACKGROUND

Anne was born in Hawthorp, Yorkshire on November 23rd, 1915. Her father, Fleetwood Pellew, was a Major in the West Yorkshire Regiment, at this time the officer commanding a prisoner of war camp in Yorkshire after being invalided out of the front line in France. Her mother, Violet du Pre, was an energetic, organising woman.

Anne was the Pelles' third child; her brother Hugo was born in 1910 and Tony in 1911. Two more boys were born, Myles in 1919 and Tim in 1921. With relatively small gaps in age between them, the children played happily together, all of them enjoying outdoor games and athletic contests, as well as more imaginative games, including some based on the Fattypuffs and Thinifers stories written by

Andre Maurois. Anne was a natural athlete who loved a challenge, and if her brothers did not provide one she made one up for herself.

Tim recalls her as being physically very brave; "she never showed fear climbing trees, and on occasion tried to help me to do the same." She egged her brothers on to do stunts involving tree-climbing and bicycles, and suggested to Myles that he might like to jump off the steeple of Arlesley church with an open umbrella.

The family moved to Bedfordshire in 1920, to Arlesley House, a large, somewhat run-down building with more than two acres of land. This was the beginning of a period of financial difficulties for the family, due to the collapse of a business venture in which Major Pellew had invested most of his money, leaving the



Anne with elder brothers Hugo and Tony. Pellew collection



Anne growing up. *Pellew collection*

family largely dependent on his small army pension. Anne's mother took charge of efforts to improve the situation. Unfortunately, the way of life to which she had always been accustomed took for granted a sizeable permanent staff to cook, clean, look after the gardens and look after the children.

Rather than cut down on staff, Tim remembers Violet's efforts to raise income by keeping rabbits for their fur skins, goats and chickens, and by breeding Samoyed dogs. "I don't think this was successful especially the dogs because they used to escape, and a

local farmer would come to the house with 30 or more dead chickens, saying our dogs had killed them and demanding payment." Around 1927 a legacy from an aunt in the form of a trust fund improved the situation, but Violet still took in "paying guests" and rented out part of the house to improve the family income.

At the age of ten Anne started as a boarder at the Abbey School in Reading. Hugo and Tony were already boarders at a prep school in Beaconsfield, so the childrens' education must have been quite a charge on family finances.



An irresistible picture of Anne and friends in girl guide uniform in the '20s. *Pellew collection*

Anne had tuition at home with her cousin Joy du Pre for some time before moving on to the Abbey School. Her mother was extremely ambitious for all the children, socially as well as academically. She insisted that Tim continue riding horses and ponies although he hated it and had several bad falls. "You had to do as a child what she wanted you to do." He found Anne more sympathetic: "I fondly remember how she would help me when I became upset at failing to make the models in "Meccano" that were illustrated. I was probably about seven years old, and she could always show me how to do it."

Near to Arlesley was RAF Henlow, an airfield Anne visited with the encouragement of Group Captain Vaughan Fowler, a family friend and member of an aviation dynasty. Henlow at that time was a military aircraft repair centre, and was later used for the training of engineering officers. Anne was deeply impressed to see aircraft take off, fly and land and decided that this was something that she very much wanted to do. She was a

very calm girl in spite of her love of activity, and would think carefully of potential risks before embarking on her more daring ventures.

Whether she thought carefully before skipping school to visit an air show at Woodley near Reading one fine day in 1927 we shall never know, but there was a tremendous row at the Abbey School when she did, and expulsion was threatened. Perhaps Anne believed that her academic and sporting achievements would bail her out. In any case she had the flight of her dreams - and remained at the Abbey School until 1932, when she was seventeen and taken out of school by Mother.

Maths was her best subject at school, and she and her mother were determined that she would get a scholarship to study this at University, and decided that she needed a higher level of tuition than the Abbey School could provide.

In 1933 the family moved across the country



Matthew Freudenberg

After a youth mis-spent drawing motorcycles instead of studying, Matthew Freudenberg did National Service in a tank regiment, studied history at University and then worked in production management in Britain and abroad.

He is now a semi-retired fruit grower in Somerset and has written several books on motorcycle and aircraft related subjects.

CLEAR AIR TURBULENCE

A Life of Anne Burns

Described by friends as "quiet", "unassuming" - even "ethereal", Anne Burns was in fact enterprising, determined and fearless in everything she undertook. A complete lack of small talk made her seem "stand offish" to some who worked with her at the Royal Aircraft Establishment at Farnborough.

Anne graduated in engineering after changing from mathematics, needing both subjects in her investigations into aircraft structural strength and flying accidents. As a flight test observer she flew in several aircraft with a reputation for crashing, and was one of the observers who flew in a Comet jet airliner that was vigorously flight tested after two of these aircraft disintegrated in mid air in quick succession on commercial flights in 1954.

Her main interest later in her career was the origin and power of wind gusts and air turbulence capable of unsettling and even destroying large aircraft. These were a particular menace to passenger aircraft flying near to jet streams, five to eight miles high.

As a child, Anne had a lively family life, with four brothers who shared her love of sport and competition. She was a successful competitive glider pilot.

ISBN 0-954-61653-7



9 780954 616533

£14.00

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