Aviation Science & Development at Farnborough

# History and Learning Briefings

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# HERMANN GLAUERT FRS FRAeS (1892-1934)

## Outstanding Aerodynamicist

Hermann Glauert was one of the most outstanding mathematicians, aerodynamicists and scientists of his time. He wrote numerous influential reports and memoranda dealing with aerofoil and propeller theory and served as Principal Scientific Officer at the Royal Aircraft Establishment (RAE) in Farnborough for many years, before a freak accident on Laffans Plain led to his untimely death in 1934.

This briefing looks at his influential works and distinguished career at Farnborough.

## Early Promise

Hermann Glauert was born on 4 October 1892 in Sheffield and educated there at King Edward VII School. In 1910 he was elected to a scholarship at Trinity College, Cambridge, arriving there close to his 18th birthday. Three years later, in 1913, he was placed in the First Class of Part II of the Mathematical Tripos, gaining distinction in the higher subjects for which he was awarded the Tyson Medal for Astronomy.

Following graduation, he undertook research in astronomy, initially under the guidance of Arthur Eddington (1882-1944). His progress was rewarded in 1914 by the award of an Isaac Newton Studentship in Astronomy and Physical Optics; followed by the Rayleigh Prize for Mathematics in 1915.

## Recruitment to Farnborough

Earlier, in 1914, as war approached, O'Gorman - the Superintendent of the Royal Aircraft Factory - had begun to build up the Factory's science and technology pool by recruiting mainly Cambridge graduates. On the outbreak of war, Glauert had continued his studies in Cambridge but, like Edward Teshmaker Busk *(see History & Learning Briefing 10),* was recruited by the Royal Aircraft Factory who were looking for top-class scientists and engineers. Glauert accepted William Farren's offer of a scientific post at the Factory and in 1916 he joined the Aerodynamics Department, of which Farren was Head.

Glauert started his research at Farnborough in studies concerning the prediction of the performance and longitudinal stability of an aeroplane. His first paper was written in 1917, in collaboration with another recent arrival at Farnborough, Sidney Barrington Gates.

FAST is developing a series of briefing on key aspects of Farnborough's Aviation Heritage.

These briefing notes are not intended to be a complete and comprehensive history of the subject of the title, but are intended to stimulate the imagination and encourage further reading. To that end, a 'further reading' list is included at the end of each briefing. By reading a number of different histories, written by varying authors over a range of timescales, a balance of the differences can be achieved – and the reader's own opinions formed. But we hope that these briefings will be an interesting summary.

It is a continuing process and a number of further briefings are planned.

**BRIEFING SERIES**

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**7.** Royal Engineers Balloon School
**8.** Royal Flying Corps
**9.** Royal Aircraft Factory
**10.** Edward Teshmaker Busk (Scientist)
**11.** Frank W Gooden (Test Pilot)
**12.** Samuel Franklin Cody
**13.** The Farnborough Wind Tunnels
**14.** Hermann Glauert (Aerodynamicist)

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For their work and comparisons with previous work of Lanchester and Bryan, Glauert and Gates drew on the recent full-scale stability tests on a B.E.2c so as to estimate the aerodynamic stability, which had been carried out by Busk *(see History & Learning Briefing 10)*.

Glauert's next paper, also in 1917, provided an assessment of full-scale elevator experiments on an R.E.8 - a tractor biplane that was beginning to replace the highly successful B.E.2c, which by then had been recognised as possessing limited performance.

## The Problem of Spin

From the earliest days of manned flight, wing stall and the almost inevitable subsequent spin - often fatal - were the least understood of aeroplane motions. In 1918, while a detailed understanding of stall still eluded Britain's aeronautical community, Glauert became involved in the understanding of spin. The RAE's Frederick Lindemann (later Viscount Cherwell) is credited with being the first to perform detailed observations whilst piloting a spinning aeroplane. The first officially to undertake this - then exceedingly dangerous - manoeuvre and recover from it to report some of its characteristics, appears to have been Farnborough's Chief Test Pilot at the time, Major Frank Gooden *(see History & Learning Briefing 11)* flying an F.E.8 biplane in August 1916. However, it is probable that others, including Sopwith's pilot Harry Hawker, had earlier discovered how to recover from a spin by centralising the rudder while pushing the stick forward.

## The 'Chudleigh Lot'

Outside normal working hours, from 1916 to 1922, Glauert lived quite happily at 'Chudleigh', a large house effectively run as a private mess by some members of the Farnborough staff, with F. M. Green, the Factory's chief engineer, as the unofficial Mess President. The permanent members were - in addition to Glauert and Green - Farren, H. Grinstead and R. M. Wood. Others, at various times, included F. W. Aston, B. M. Jones, F. A. Lindemann, D. H. Pinsent, G. I. Taylor, G. P. Thomson and H. A.

Life at 'Chudleigh' appears to have been congenial with a stimulating atmosphere, which no doubt helped support the pioneering work being undertaken at Farnborough at the time. Many years later S. B. Gates recalls of the 'Chudleigh lot' that *"…they were said to play erudite games like three-dimensional chess when they were not analysing what the day's inspiration and observation brought them. They were as wildly individualistic as any élite are - and about twice as hardworking."* [1]

LEFT : Aerodynamics Department, RAE, 1918. Believed to be, from left to right up the steps; Glauert, Thomson, Lindemann, Grinstead, Farren, R. Hill, Pinsent. Centre foreground: Bairstow and R. M. Wood. *(FAST Archives)*

[1] J. A. D. Ackroyd & N. Riley: Hermann Glauert FRS, FRAeS (1892 – 1934) Royal Aeronautical Society Journal of Aeronautical History Volume 1, Paper No. 2011/ 2

## Research and Recognition

Shortly after the end of the war Glauert went to Göttingen with Ronald McKinnon Wood, who had succeeded Farren as Head of the Aerodynamics Department. The main purpose of their visit was to assess Prandtl's new return circuit wind tunnel with its novel 5:1 contraction ratio upstream of the working section. However, what Glauert found at Göttingen was the seminal work on wing theory that had been carried out by Prandtl, Betz and Munk. This had a profound effect upon his own research in the years ahead.

Hermann Glauert's research prospered over the following years at Farnborough and he was constantly at the service of the Aeronautical Research Committee (ARC) for advice on all forms of aerodynamic problems. Indeed, all of Glauert's work in aeronautics sprang from his career at Farnborough. The vast majority of his published papers appeared as Reports & Memoranda (R & M) of the Advisory Committee for Aeronautics (ACA), which in 1920 became the ARC. All but one of his papers can essentially be divided among four research areas: aeroplane performance, including stability and control; aerodynamics; propeller performance; autogyros and helicopters.

By the early 1930s he was one of the world's leading aerodynamicists, his stature recognised by election to Fellowship of the Royal Aeronautical Society in 1926 and, in 1931, Fellowship of the Royal Society. Glauert was the first serving member of the RAE to be so honoured. Shortly afterwards he succeeded Wood as Head of the Aerodynamics Department.

## Development of the Prandtl-Glauert Method

Glauert is possibly best known for his development of the work of Ludwig Prandtl, the German scientist who pioneered the development of rigorous systematic mathematical analyses which have come to form the basis of the applied science of aeronautical engineering. Glauert's book 'The Elements of Aerfoil and Airscrew Theory' was probably the single most important publication for spreading Prandtl's airfoil and wing theory; as well as advancing the fundamental principles of aerodynamics.

Glauert went on to independently develop the Prandtl-Glauert method from the then existing aerodynamic theory. The method was published in the Proceedings of the Royal Society in 1928. The Prandtl-Glauert singularity is the prediction by the Prandtl-Glauert transformation that infinite pressure conditions would be experienced by an aircraft as it approaches the speed of sound. This was related to the misconception, at this time, of the impenetrability of the 'sound barrier'. Although this misconception was theoretically correct, it was found that it was not valid to apply this type of transformation at these speeds. A mathematical singularity is a point at which a given mathematical object is not defined. For example, f(x) = 1/x has a singularity at x=0 where it reaches +/_ infinity.

In 1926 Glauert published a lengthy and detailed mathematical analysis of the autogyro, the analysis being subject to a number of simplifying assumptions. In 1928 Glauert and Lock (at the NPL) combined to produce a summary of current findings on autogyro characteristics. They described the demonstration of the Cierva C.6 at the RAE and the subsequent responses of the RAE and NPL they had previously studied. Having summarised the theoretical and experimental results obtained, they concluded that their results were in satisfactory agreement on all essential points. From this they judged the autogyro's performance to be inferior to that of corresponding aeroplanes. However, the autogyro possessed the valuable qualities of stability at large incidence angles and ease of landing.

ABOVE : Cierva C6A at Farnborough, October 1925 *(FAST Archives)*

## Helicopter Performance, Wind Tunnels and Propellers

Earlier Glauert had been asked to develop a theory for helicopter performance and in 1927 he issued his first paper on the subject. In his second paper he deals with the helicopter in horizontal flight and discusses the condition where, if the blades are rigid in forward flight, a rolling moment would be created by the advancing blade having a greater lift than the retreating blade. To remove this moment, Glauert suggests either hinging the blades at their roots so as to allow them to flap up and down freely; or alternatively arranging for a periodic variation of blade angle during each revolution. The latter suggestion was later universally adopted.

In 1931 Glauert returned to his work on wind tunnel interference effects started in 1928, interrupted by a short academic diversion into wing theory. In 1933 his comprehensive survey of wind tunnel interference effects was published as a separate monograph.

His last publication, published posthumously in 1935, was a review on propeller theory. It was notable for its scholarly accuracy, describing the theory's historical development and his (and others') research at Farnborough and NPL. It stands as a significant memorial to an outstanding career.

## Untimely End

On August 4th 1934, driving with his family and his elder brother Otto, Glauert was stopped near Norris Bridge by a team of Royal Engineers blasting tree stumps to extend the flying area at Laffan's Plain. Tragically, standing at an allegedly safe distance, Glauert was struck by a large piece of debris and died shortly after. *(Farnborough Chronicle*, *Friday, August 10th, 1934*). He is buried in Ship Lane Cemetery in Farnborough and was joined in 1949 by his wife Muriel, also an RAE aerodynamicist.

*Glauert lived during a period in which massive advances were made in the understanding and description of aerodynamic phenomena. Yet he was an acknowledged master of his subject and it has been said that his book, 'The Elements of Aerfoil and Airscrew Theory', remains the most lucid and best organised introduction to the fundamental principles of aerodynamics that has ever been written.*

**FURTHER READING**

J. A. D. ACKROYD & N. RILEY: Hermann Glauert FRS, FRAeS (1892 – 1934) Royal Aeronautical Society Journal of Aeronautical History Volume 1, Paper No. 2011/ 2
*Authors note: This first reference by Ackroyd & Riley is by far the most complete history of Glauert's research, on which this brief summary is based and this reference needs to be the first port of call for all serious researchers.*

WOOD, R. M. Recollections 1914-1934, *JRAeS (Centenary Journal)*, January 1966, 70, (661), pp 89 - 90.

Article by Dr Graham Rood 2012