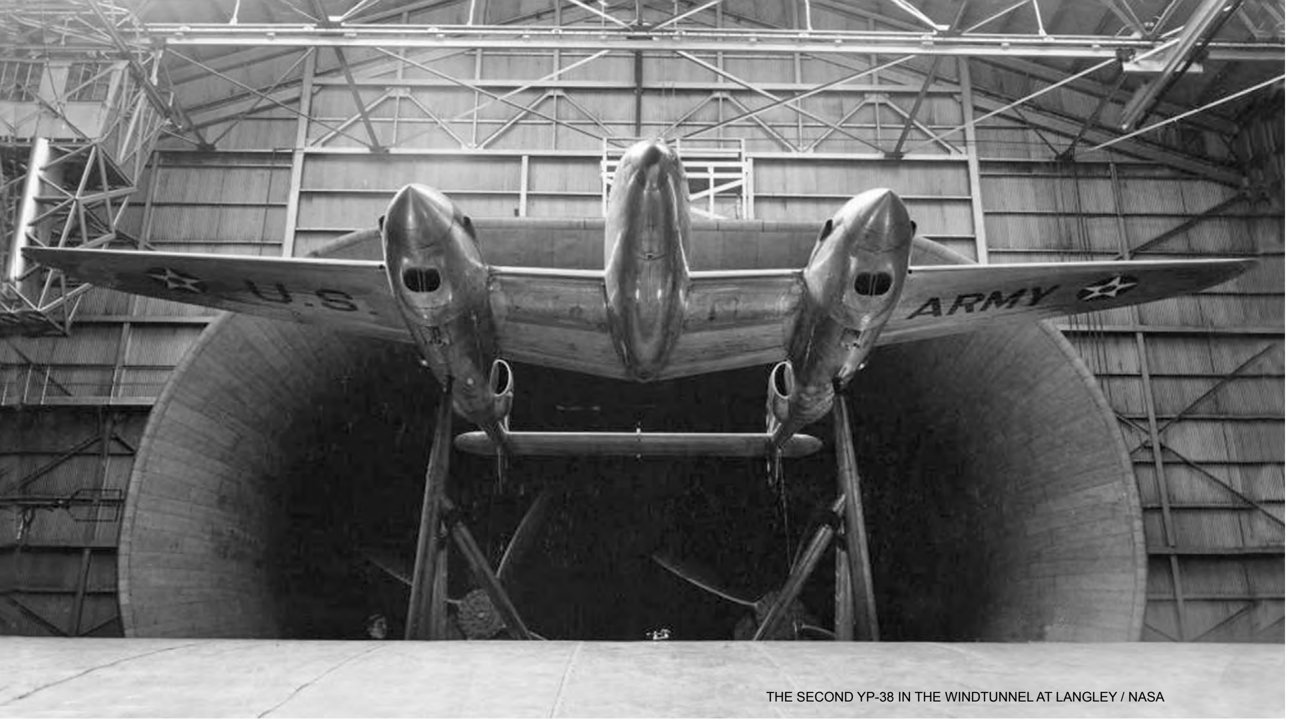

THE SECOND YP-38 IN THE WINDTUNNEL AT LANGLEY / NASA

LOCKHEED CONSTERNATION

Compressibility & the P-38 Lightning

In the concluding article in his three-part series on aerodynamic developments during a critical period of experimentation, **MATT BEARMAN** argues that the problems caused by the unique shape of the Lockheed P-38 had already been solved by the time its co-designer, Clarence "Kelly" Johnson, was forced to look at the problem of compressibility

THE HISTORY OF Lockheed's distinctive P-38 Lightning is well known. According to the legend, it was a stunning design that flowed in part from the genius of the best aircraft designer in the world. It was the "fork-tailed devil" that took on the Luftwaffe in ways nothing else could, but which had a flaw: its wing caused compressibility problems. At Mach 0·68 the P-38 began shaking violently, and soon after would pitch down into a dive that only gentle application of the trim tabs could resolve.

The myth continues; nobody could have predicted this — the Lightning went faster than everything else, so it was the first to encounter the speed of sound over its aerofoils (notwithstanding Messerschmitt test pilot Kurt Jodlbauer's July 1937 death in a Bf 109 during a high-speed dive test, in which the aircraft experienced compressibility and plunged into Lake Muritz). Eventually some clever people at Lockheed, led by chief designer Clarence "Kelly" Johnson, who could "see air", worked out the complex mathematics for the first time and came up with a solution to the uncontrollable dives the aircraft would pitch into at speed and all was well again. That story may sound familiar, but every part of the last sentence is almost certainly nonsense.

Johnson, a research engineer under the leadership of chief designer Hall Hibbard at the time of the P-38's inception, later remarked: "I broke an ulcer over compressibility on the P-38. We flew into a speed range where nobody had been before, and we had difficulty convincing people that it wasn't the funny-looking aircraft itself, but a fundamental physical problem . . . we worked through the whole war to get 15kt more speed out of the P-38 — we darn near doubled the power. We saw compressibility as a brick wall for a long time. Then we learned how to get through it, and we went Mach 2 with the F-104 and beyond Mach 3 with the [SR-71] Blackbirds".[1]

LEFT ***Clarence "Kelly" Johnson joined Lockheed in 1933 and established his reputation with work on the Lockheed 10 and other predominantly civil types, before being appointed chief research engineer in 1938. The P-38 was the result of a February 1937 USAAC Specification, with Johnson playing a major part in its design under the supervision of the company's chief designer, Hall Hibbard.***

Although Johnson established a reputation for straight-talking, he never really managed it when it came to the P-38. An effective change that would move "the wall" back 50 m.p.h. (80km/h) had been proposed and demonstrated at least twice before the dive flaps ultimately fitted to the P-38 as a solution were tested. It now also appears likely that Johnson's own research engineering team had produced a better solution as early as September 1941 — and then for its own reasons failed to adopt it.

FASHION VICTIM

The P-38 was arguably something of a fashion victim. In the decade before Johnson put pencil to paper everything was designed with copious use of the "streamline", or elongated egg shape. The trouble is that this shape is an aerofoil, and aerofoils accelerate the air passing over them relative to themselves. The parcel of air moving over the "shoulder" of the P-38 is accelerated by two aerofoils at once; one created by the flanks of the egg-shaped cockpit nacelle, and one created by the wing. In terms of pressure gradients and velocities, the air behaves as if it was being acted on by one combined "virtual aerofoil" of much greater thickness than the wing alone. A consequence of this is early flow separation (also known as burble), which, when it hits the tail, is called buffeting. Another is greatly increased wave drag (see glossary on page 21) and reduced critical Mach (ditto).

That the P-38 had no rear fuselage, but held a narrow-chord tailplane by means of two booms trailing behind the engines instead, is not particularly unusual. Several other aircraft made use of this expedient, including its near-contemporaries the Northrop P-61 Black Widow and the Focke-Wulf Fw 189. The Dutch had already mass-produced the elegant Fokker G.I. All had a design feature that the P-38 did not — the continuation of the fuselage pod aft of the wing junction. Adopting this staggered configuration meant a reduced pressure gradient and a lower induced velocity over the wing root for the G.I — a good thing. However, even without going into the mathematics (which Johnson was fully capable of doing), the empirical evidence alone showed that aligning the P-38's wing junction trailing edge with the aftmost point of the fuselage pod would create a problem.

In his report on model tests in the National Advisory Committee for Aeronautics (NACA) variable-density windtunnel as early as 1937, aerodynamic pioneer Eastman "Jake" Jacobs stated that "the interference burble does not appear when the wing is in the most forward mid-wing position, but is present for the second position back and occurs progressively earlier as the wing is moved backwards from this latter position".[2] This much was known, and most designers kept wings well forward on bodies.

At a lecture given at the Fifth Volta Conference in Rome in 1935, the same Dr Jacobs presented the earliest scientific observations of supersonic shock behaviour in the USA. As early as this, Jacobs was able to show that "the critical Mach number could be increased by shape changes which could be determined through observation of burble in low-speed tests".[3] The onset of burble and supersonic shock were related.

This latter connection did not seem to be worthy of discussion among the more "fashionable" aerodynamicists of Johnson's generation. Until at least 1944, higher-speed burble around wing roots behind the maximum thickness, while a known problem, was largely misidentified in the