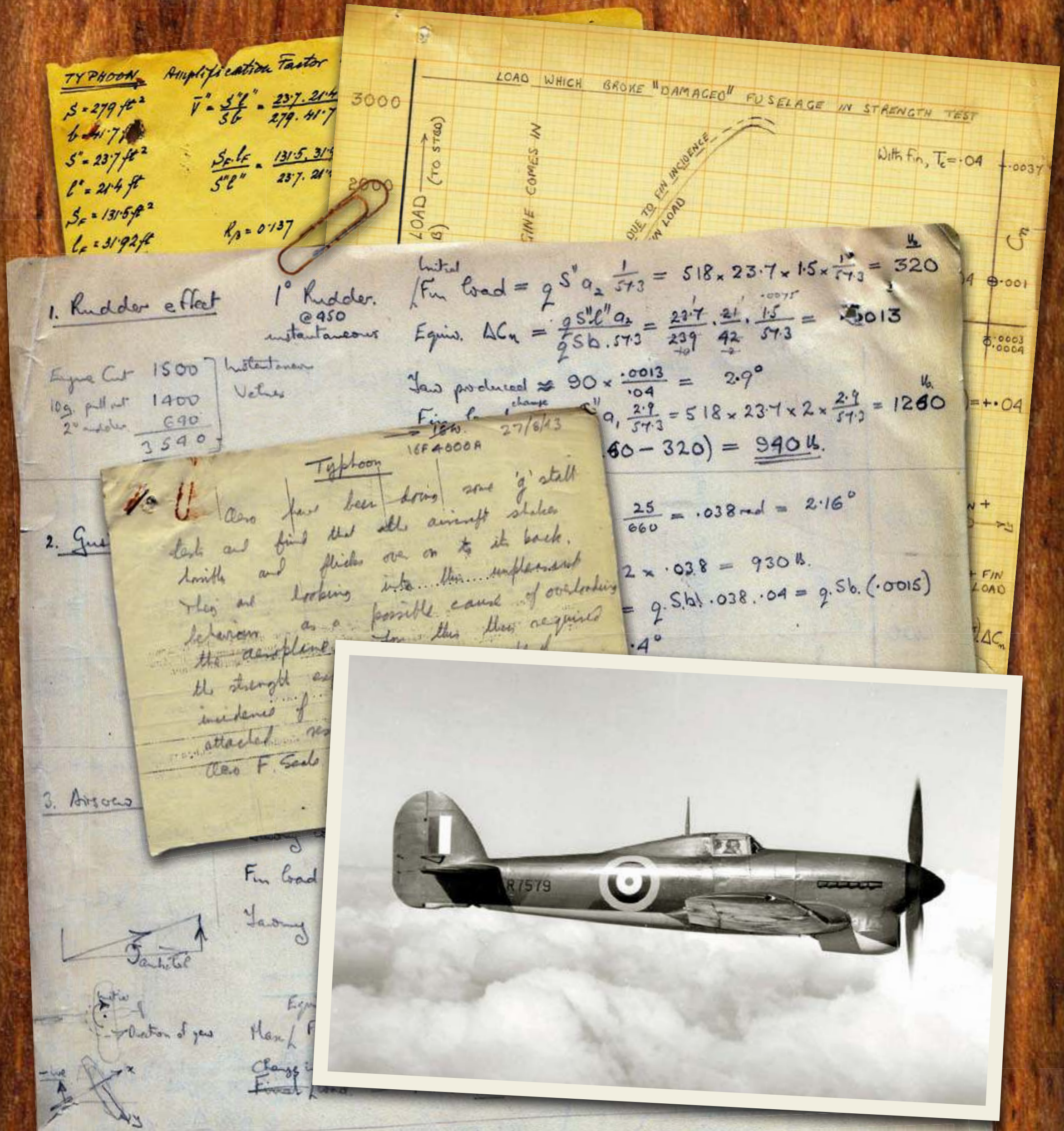


Bad Vibrations

Solving the Hawker Typhoon's structural problems

Digging deep into the archives, **RICHARD SETH-SMITH** uses contemporary documents, and a recently rediscovered letter written by Hawker's chief test pilot Philip Lucas in 1976, to piece together a trail of evidence revealing exactly how Hawker and the Royal Aircraft Establishment solved the structural problems that blighted the Typhoon's early career — and which killed his test-pilot father

DURING 1942–43 more than 25 pilots were killed in incidents in which their Hawker Typhoons broke up in flight. All but one were Service pilots, the exception being Kenneth Seth-Smith, Hawker's experimental test pilot — and my father. Much has been written about the aircraft and its development into the potent ground-attack machine that would play a major part in the Normandy campaign and the Allied advance into Germany. However, the causes of — and solutions to — the structural problems which plagued the type's early service have never been fully explained in books and articles, other than by oblique references to vibration and other issues. Now, through the content of a rediscovered 1976 letter from Hawker's chief test pilot, Philip Lucas, to John Grierson, Hawker and later Gloster test pilot, and extensive research by the Farnborough Air Sciences Trust (FAST), the causes and solution can be fully explained.

Gloster production

The history of the early development of the Typhoon is well-known, so we join the story after the initial batch of 15 had been completed at Langley and the production programme shifted to Gloster's Brockworth factory. All experimental and development testing remained based at Langley, which had good links both to Hawker's offices at Kingston-upon-Thames and the manufacturer's rehoused engineering and design headquarters at Claremont, an 18th-Century Palladian mansion near Esher in Surrey.

The Typhoon's 24-cylinder sleeve-valve Napier Sabre engine, although capable of producing some 2,200 h.p., was suffering from significant reliability problems, and it soon became apparent that hopes for good high-altitude performance from the type were not going to be met, owing to its thick-section wing. Nevertheless, the Typhoon was meeting its specified target of 400+ m.p.h. (645+km/h) at 25,000ft (7,600m).

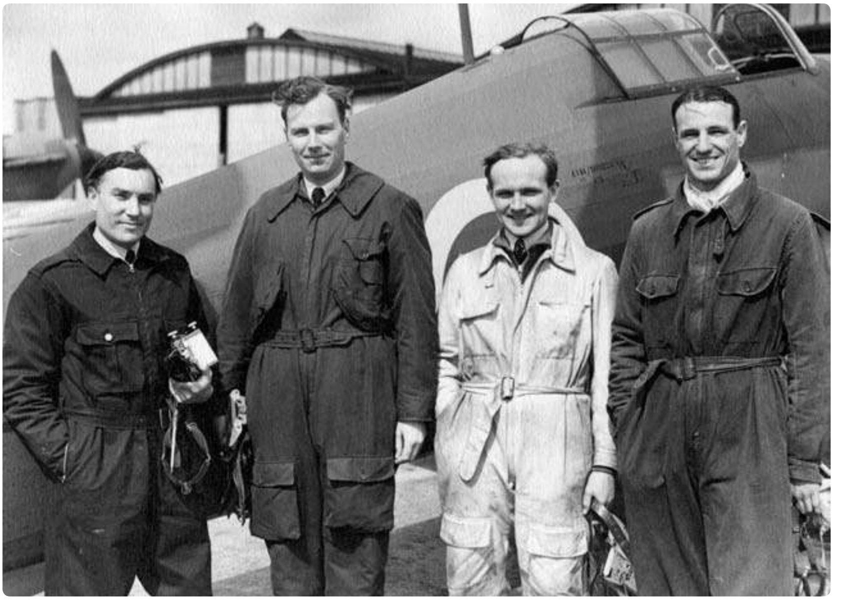
Typhoon production began at Gloster in August 1941, with first deliveries to squadrons beginning that September. The first batch of 250 machines was completed by June 1942 and the second batch of another 250 by September of that year. Early squadron experience with the machine was often difficult. Serviceability was low, engine failures frequent and the aircraft was not easy to fly. Compared to the Hurricanes and Spitfires that pilots had previously experienced, it was heavy on the controls and unforgiving. There were accidents and losses, but this was to be expected with a new type of aircraft entering service.

Some sources suggest that two Typhoons crashed in late 1941 or early 1942 owing to tail failure. It is known that R7592 dived into the ground on November 1, 1941, possibly owing to carbon-monoxide poisoning of the pilot, and that R7618 crashed in bad visibility on May 13, 1942. Before that, R7637 had spun into the ground on March 8, 1942, and R7625 had crashed before delivery on March 27, although in none of these cases was structural failure thought to be the cause. The first Typhoon accident in the RAF Museum's accident-card files specifically to state structural failure occurred on July 29, 1942, when R8633 of No 257 Sqn crashed 2½ miles (4km) from its base at High Ercall in Shropshire, with a mere 5½ flying hours on the clock.

The squadron was in the process of swapping its Hurricanes for Typhoons and the pilot, Plt Off McDunnough, although experienced, had just 1½hr on the latter. The accident report reveals that, following authorised aerobatics at about 15,000ft (4,600m), the aircraft "then came down in a straight shallow dive at a high but reasonable speed, with engine partly throttled-back, to

OPPOSITE PAGE ***The fourth production Typhoon, Mk IA R7579, shows its characteristically muscular Hawker design during an early test flight.*** **BELOW** ***The Mk IB differed from the IA in being fitted with four Hispano 20mm cannon in place of the latter's six 0·303in machine-guns. This example, R7646, went on to serve with No 56 Sqn.***

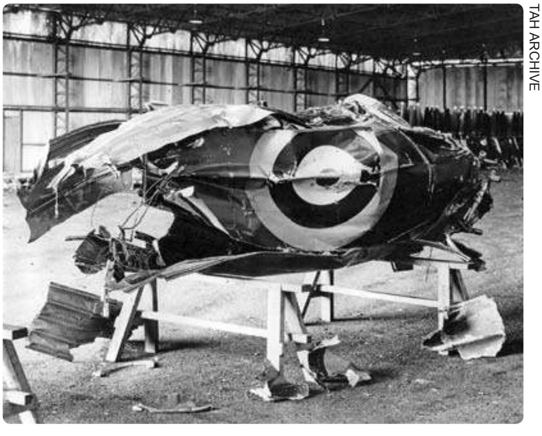
TAH ARCHIVE x 2



AUTHOR'S COLLECTION

LEFT ***The Hawker test-pilot team in 1939. From left to right: chief test pilot Philip Lucas; John Grierson, production test pilot; Kenneth Seth-Smith, production and later experimental test pilot; Australian Dick Reynell, experimental test pilot, who was killed in action while flying a Hurricane with No 43 Sqn in September 1940.***

BELOW ***Part of the wreckage of Typhoon IB R7692, in which the author's father was killed while performing a relatively simple test-flight from Langley on August 11, 1942. Exactly a week later another Typhoon IB, R7644, was lost under similar circumstances.***



TAH ARCHIVE

between 2,000ft [600m] and 4,000ft [1,200m], when it began a turn to starboard with no noticeable flattening out and the tail unit broke away, falling in three pieces". The report continues:

"Examination of the wreckage found that the tail unit had broken away at or aft of Frame K [the transport joint — see glossary on page 77]. This, without the port tailplane and elevator, rudder or mass-balance, was recovered about a mile [1·6km] from the main wreckage. The port tailplane with elevator was [found] a quarter of a mile [0·4km] further on. The elevator mass-balance was found slightly ahead of the main wreckage."

Another mysterious tragedy

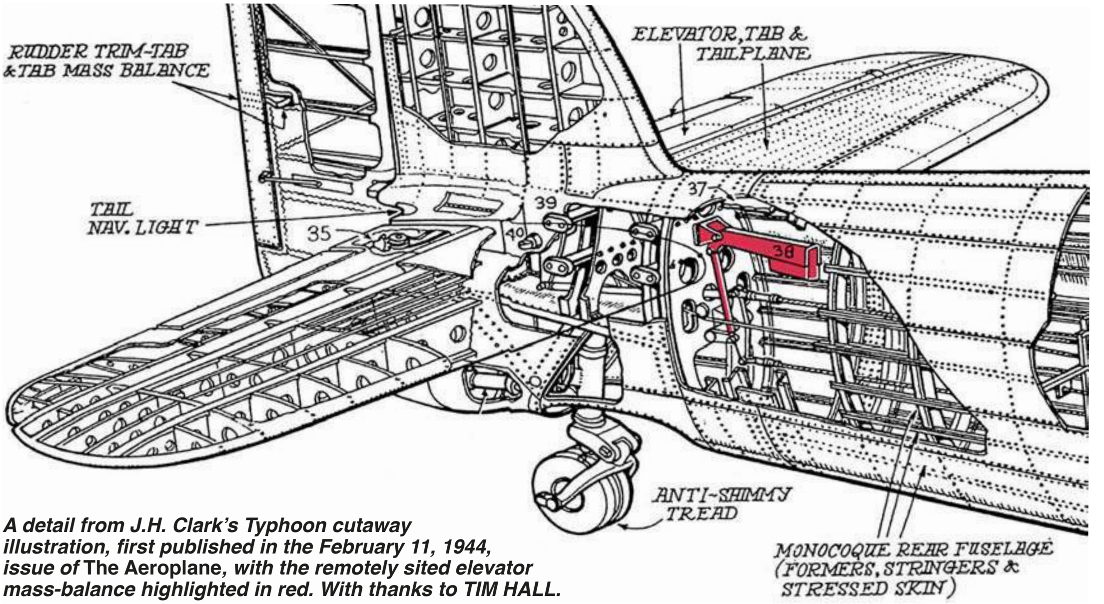
Less than two weeks later, on August 11, 1942, R7692 crashed at Thorpe, Surrey. This, however, was no squadron aircraft, but a Typhoon based at Hawker's Langley flight-test centre and flown by experienced Hawker test pilot Kenneth Seth-Smith. The Hawker establishment was shocked to the core according to Charlie Dunne, Seth-Smith's flight engineer, who had despatched the flight.

The purpose of the sortie, as detailed in the accident report, was to investigate level speeds and handling with the top panel of the cockpit canopy removed. No extreme manœuvres, maximum-speed dives or aerobatics were undertaken. The aircraft had already been flown twice that day in normal condition. An eyewitness stated:

"Shortly before the accident happened he had been seen flying at between 2,000ft and 4,000ft, then climbing and turning to port, followed by a rising engine note. Immediately afterwards there was a loud report and the aircraft broke cloud in an inverted spin with engine stopped, until it struck the ground followed by parts of the tail unit."

The detailed accident report, which remained a classified document in the files of the Royal Aircraft Establishment (RAE) at Farnborough for decades, came to light when the files were transferred to FAST to be catalogued. A friend there passed the report to me some ten years ago; it was the first time the family became aware that such a report even existed. In its original hand-written form, and with detailed hand-drawn diagrams of the wreckage path and the failed fuselage components, it cast light on the results — but not the cause.

Structural failures at that time were sometimes caused by flutter (see glossary) or distortion, but detailed inspections of Service Typhoons failed to indicate any progressive weakening or distortion of other airframes. The elevator was the primary suspect in the subsequent enquiry. The elevators were balanced by a remotely sited mass, operated through a series of rods connected to a bracket mounted on the bulkhead ahead of the tailplane. Today, the type would almost certainly have been grounded until cause and rectification could be



A detail from J.H. Clark's Typhoon cutaway illustration, first published in the February 11, 1944, issue of* The Aeroplane*, with the remotely sited elevator mass-balance highlighted in red. With thanks to TIM HALL.

established, but "there was a war on" and such action could not be countenanced.

While accidents in new aircraft were not uncommon in squadron service, the loss of a test aircraft flown by an experienced test pilot most certainly was. With alarm bells ringing loudly at Hawker and elsewhere, a top-level meeting was held the day after Seth-Smith's accident, attended by Hawker designer Sydney Camm, his number two Roland "Roy" Chaplin, other Hawker personnel and representatives of every RAE department. That the accidents of July 29 and August 11 were the first mid-air break-ups seems to be confirmed in the later accident report by the mention of a visit on August 15 by two senior RAE personnel to Duxford, where the Typhoon was in service with No 609 Sqn, "following two mid-air structural failures".

According to Philip Lucas, every subsequent unexplained accident had to be referred from squadrons to Langley, with the wreckage being examined there and/or at the RAE. At a meeting on August 28, 1942, ten days after R7644 of No 56 Sqn had crashed under similar circumstances, all parties agreed that strengthening of the transport joint should be undertaken, along with the mass-balance mechanism, as the RAE considered that failure of the latter could cause elevator flutter.

Testing continues

Meanwhile, development and production of the Typhoon continued, the flight-test schedule at Langley being undertaken by Lucas, Bill Humble, Merrick Hymans, John Crosby-Warren and Plt Off Roland Beamont, the latter completing occasional spells as a Hawker test pilot during 1941–43. It can't have been an easy task for the pilots, taking aircraft aloft without any knowledge of the causes of the crash which had killed their colleague.

Glossary Compiled by Matt Bearman

Mass balance A weight attached to an arm intended to damp the movement of a control surface by countering it with inertia

Inertia weight Often fitted near the base of the control column, this mass gives additional resistance to control movements to prevent involuntary overcorrection or excessive feedback through the column from aerodynamically affected control surfaces

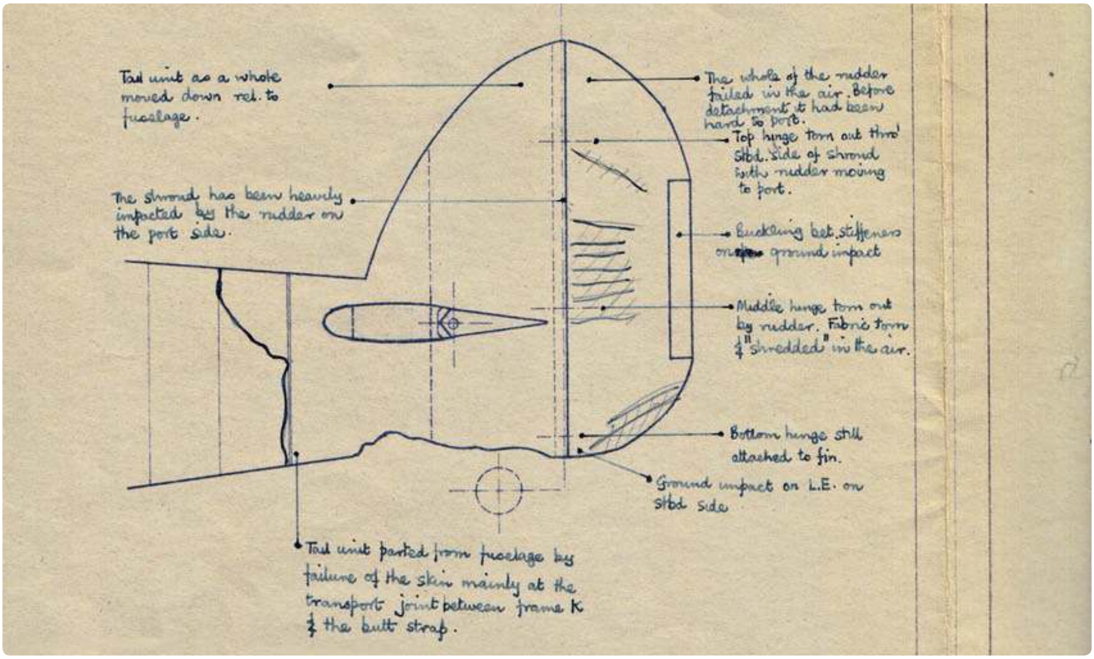
Flutter When a control surface or sometimes a flying surface begins oscillating uncontrollably owing to the alternate action of airflow on upper and lower surfaces

Transport joint A "natural break" in an airframe, held together by fasteners that can be simply removed for dismantling

Natural frequency The frequency of oscillation at which a given object will vibrate with the minimum input of energy, and continue to vibrate after the energy input is removed. Different-shaped objects with varying stiffnesses and mass distributions will all have different natural frequencies

Resonance What happens when an object is encouraged to vibrate at its natural frequency — usually best avoided in engineering. In the case of the Typhoon, it appears that tail flutter alone was not the problem; rather it was aeroelastic flutter hitting a fundamental frequency of the whole system, with stress concentrated in the rear fuselage

Rudder reversal This is usually owing to the "tail wagging the dog" — a large rudder input putting a bending stress on the tail, deflecting it enough for aerodynamic forces to yaw the aircraft the opposite way to that intended. The tail springing back elastically from this state, coupled with sufficient freedom of movement of the rudder, can begin the oscillations leading to flutter



AUTHOR'S COLLECTION

ABOVE ***One of the meticulously hand-drawn illustrations from the official accident report into the crash of R7692, showing the points of structural failure in the rear fuselage. The bottom handwritten caption states that the "tail unit parted from fuselage by failure of the skin mainly at the transport joint between frame K and the butt strap".***

The RAE at Farnborough had already researched various aspects of the Typhoon's design and behaviour. In early 1941 it had investigated the strength of the type's rear fuselage, and later work included windtunnel tests looking into the problems of CO_2 ingress to the cockpit and other aspects of the cockpit design from May 1942, as well as investigating the type's tendency to swing on take-off. The structural failures then started to feature heavily in research work on the type.

The next 18 months saw the issue of more than a dozen reports on work undertaken at Farnborough into the aircraft's structure and behaviour under various flight conditions. This continued in parallel with efforts at Kingston to reinforce the type's rear fuselage in the area of the failures. In his letter, Lucas states that "one of the most intensive accident investigations of the war was mounted by Hawker and the RAE, including some pretty hair-raising flights from Langley specifically to try to find out what happened".

Unfortunately the Hawker design team's efforts to overcome the problem cannot now be fully investigated. On the closure of the Kingston factory in 1992, almost all of the records and all the drawings were scattered or destroyed, although BAE Systems Heritage at Farnborough retains the Master Drawing List of modifications issued at the time, with a very brief description.

In contrast, the RAE's efforts are extremely well documented, with copies of its copious communications with Hawker, the Ministry of Aircraft Production (MAP) and others. Dated less than two weeks after the Seth-Smith accident, SME Test Note 534 gives the results of strength tests on the elevator mass-balance arm in three different directions.

Concern grows

Next came a report by the RAE's Structural & Mechanical Engineering (SME) department on the crashes of R8633 and R7692, dated September 15, 1942, following the discovery of cracks to the tailplane spar-webs of the aircraft. It concludes:

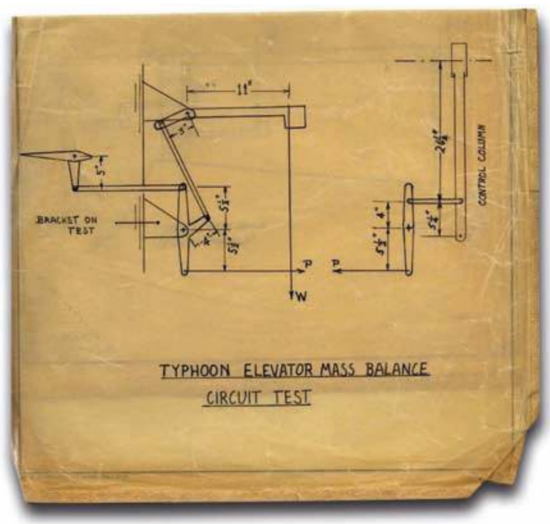
"[The] tailplanes are not working near their margin of strength. The loading under which fatigue failures of spar-flanges develop is not that under which [the] tailplanes failed in flight. Failures of the fuselage at, and in front of, the transport joint preceded any failure of the tailplane. Much of the damage seen to the tailplanes was caused by them being 'towed' by control cables following separation."

Strengthening of the Typhoon's fuselage and tailplane began with Modification (Mod) No 256, issued in late September 1942, simply titled *"Tail Plane — Strengthened"*, which incorporated fixes to ensure no spar-cracking.

By October 23, 1942, SME was developing g-proof in-flight strain-gauges and recorders. At a meeting at the MAP on October 29, attended by Sydney Camm and members of his staff, it is recorded that there was a consensus that "failure of the elevator mass-balance was previously considered the most likely cause of the failures, but it is now generally agreed that this is not the primary cause. Loads caused by rudder reversals [see glossary on page 77] are considered to be

FAST VIA AUTHOR x 2

ABOVE ***A Typhoon model in the high-speed windtunnel at RAE Farnborough. The tunnel was opened in November 1942 and was designed to test scale-models of up to 6ft (1·8m)-span at windspeeds up to 600 m.p.h. (965km/h).*** **BELOW** ***A contemporary schematic showing the circuit-test details for the elevator's mass-balance system.***



very significant". At this meeting it was also agreed that rubber engine-mountings and a four-bladed propeller should be introduced as soon as possible to minimise the transmission of vibration into the fuselage. In his letter, Lucas confirms that "the elevator mass-balance was quite a well-engineered job and was not suspect[ed] by RAE".

In November 1942, after another loss — R7695 of No 266 Sqn on October 24, involving the loss of its tailplane — a Hawker document was issued advocating further strengthening measures. These were all aimed at the reinforcement of the area around the transport joint and the structure attaching the tailplane. Major investigations then concentrated on the effects of yaw owing to rudder reversal, sideslip and loss of power.

Between October and December 1942 the RAE's Aerodynamics Department produced six reports, all from windtunnel work. Two of these trials used scale models, looking into moments on the tailplane, the remainder being in the 24ft (7·3m) windtunnel using full-size machines. These trials looked at hinge moments on the elevator, yawing-moment measurement, the effect of slipstream on the torsion of the rear fuselage and the effect of slipstream and yaw on the bending moments of the rear fuselage.

The mystery deepens

Meanwhile, the test-flying programme continued apace. The trials aircraft were heavily instrumented, recording readings from the flight instruments as well as the output of strain-gauges fitted to various parts of the empennage. This instrumentation took up the entire radio compartment so no radio equipment was carried. For that reason, every sortie was carefully planned and rigidly adhered to in case of trouble or failure. Lucas notes in his letter:

"These flight tests didn't show [up] any sign of structural weakness, despite deliberate mishandling under every conceivable flight manœuvre. But we couldn't tell the squadrons that we were completely baffled."

By the end of January 1943 three more Typhoons — DN532 of No 245 Sqn on January 13; R7854 of No 56 Sqn on the 17th and DN364 of No 197 Sqn on the 28th — had been lost owing to tail failure.

ABOVE & RIGHT ***The wreckage of DN510 at Meavy, on the south-west edge of Dartmoor in Devon, after its tailplane failed on February 4, 1943; the only instance of such an accident in which the pilot lived to tell the tale. Note the static balance lever still attached to the bracket on the bulkhead in the photograph at right. In some of the earlier tailplane failures the lever had sheared off from the bracket altogether.*** FAST VIA AUTHOR

Then on February 4, 1943, Typhoon IB DN510 of No 193 Sqn, based at Harrowbeer in Devon, was on a test to height when its tailplane failed. This is the only Typhoon tail separation to have been survived by the pilot, although another survived an in-flight break-up in late 1944, which may have been due to other factors.

The pilot of DN510, Plt Off A.W. Kilpatrick, reported that at about 27,000ft (8,200m) he moved the controls forward and then commenced an aileron turn, but after turning through about 270° he experienced severe buffeting, such as that induced by very bumpy conditions, so took off aileron. At about 380 m.p.h. (610km/h) indicated airspeed (IAS) he then attempted to ease out of the dive, but there was little response, so he immediately throttled back and eased the stick forward slightly, then back without result.

The aircraft then began turning to port, and when an attempt was made to correct this with rudder there was a "terrific bang"; the canopy flew off, some seat-straps failed and Kilpatrick was partly thrown out. He managed to regain his seat, released the other straps and was thrown clear. He pulled his ripcord and alighted on *terra firma* with injuries to scalp, eyes and legs. Eyewitnesses confirmed that the tail had separated, landing half a mile from the main wreckage, which burned out. Kilpatrick had accrued a total of 210 flying hours, four of which were on Typhoons; his clear description of the event confirmed the rapid catastrophic failure of the aircraft — but offered no clues as to the root cause.

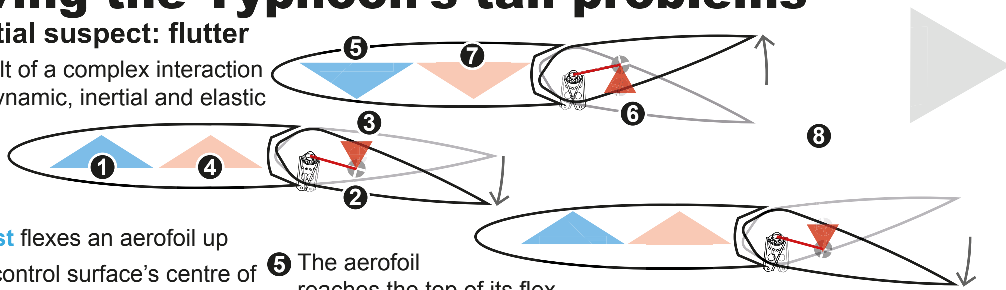
Research continued at Hawker and the RAE, with in-depth examination of every conceivable cause of the Typhoon's tail failures. The next stage was to reinforce further the transport joint during production, and provide a retrofit pack for the squadrons. First mentioned by Camm at a meeting back in November 1942, this involved riveting fillets or "fishplates" to every stringer — all 20 of them — across the transport joint. This modification, Mod No 286, was introduced on February 22, 1943. It would be some time before all delivered aircraft were updated with Mod 286, but even when they were, with all production machines included, the failures continued.

In March, April and May 1943 four aircraft — DN481 of No 609 Sqn; DN265 of No 56 Sqn; EJ932 of No 266 Sqn and EK186 of No 174 Sqn, all fitted to Mod 286 standard — were lost, although at least one of these may have been owing to extraneous factors. What now appeared to be occurring was failure either in front of, or behind, the

Solving the Typhoon's tail problems

The initial suspect: flutter

The result of a complex interaction of aerodynamic, inertial and elastic forces

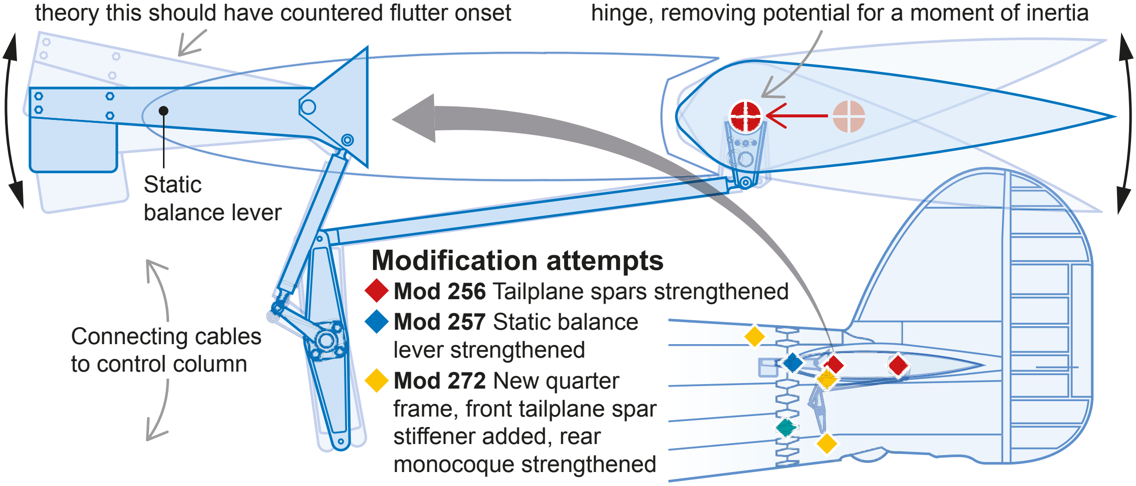


1. A **gust** flexes an aerofoil up
2. The control surface's centre of gravity is behind the hinge …
3. … so a **moment of inertia** causes it to deflect down
4. Increasing lift, adding energy to the wing's upward flex
5. The aerofoil reaches the top of its flex
6. The control surface's inertia keeps it moving upwards …
7. … adding to the subsequent downward flex
8. Depending on frequency, this oscillation can continue or even increase dangerously

Mass balance

The elevator was fitted with a mass balance. In theory this should have countered flutter onset

The balance advanced centre of gravity to the hinge, removing potential for a moment of inertia

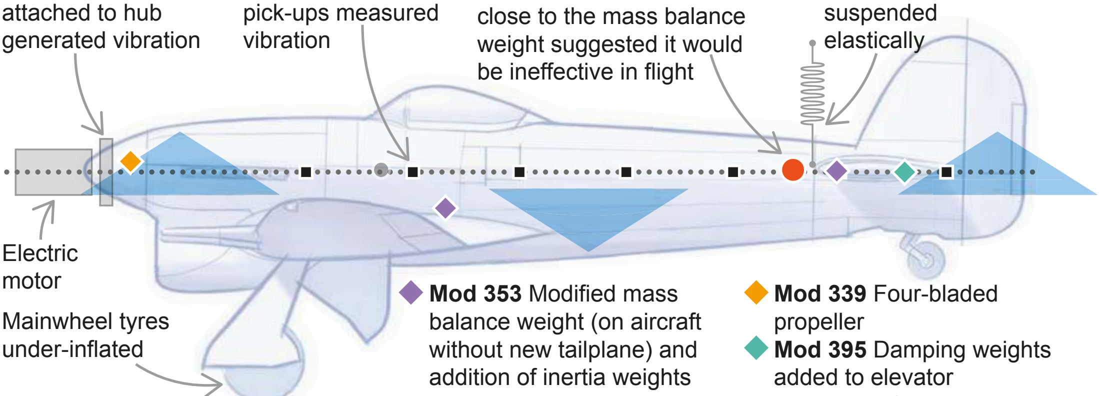


Modification attempts

- **Mod 256** Tailplane spars strengthened
- **Mod 257** Static balance lever strengthened
- **Mod 272** New quarter frame, front tailplane spar stiffener added, rear monocoque strengthened
- **Mod 286** Transport joint strengthened with external plates

The resonance test that discovered the problem

It wasn't just the tail oscillating at a fundamental frequency, it was the whole aircraft



- **Mod 353** Modified mass balance weight (on aircraft without new tailplane) and addition of inertia weights to control column
- **Mod 339** Four-bladed propeller
- **Mod 395** Damping weights added to elevator (unsuccessful)

Graphic: Ian Bott
www.ianbottillustration.co.uk

TAH ARCHIVE

ABOVE ***With the distinctive fishplates added at the transport joint as per Mod 286 clearly visible immediately aft of the serial, the wreckage of EK186 awaits further inspection after having broken up in mid-air near Redhill on May 4, 1943. The cause of these failures continued to mystify the investigation teams at Hawker and the RAE.***

heavily reinforced transport joint, rather than at it.

It had been noted that in almost every failed-tailplane case, a lateral wrinkle had occurred immediately forward of the fin. This was also seen on squadron aircraft, including those which had been fitted with Mod 286. Curiously, despite repeated strength-testing, the RAE never managed to replicate this wrinkling on a test rig.

Further experiments

In early March 1943, Arthur R. Collar, leading SME's activities on the Typhoon at the RAE, visited Hawker to review all activities. It was confirmed that flexible engine-mountings had been approved for future production. This would considerably reduce vibration throughout the airframe. Hawker reported that its strain-gauge measurements had been concluded. Completed using Rotol equipment, these recorded tailplane spar stresses, elevator angle and accelerations at "between 200 and 250 [m.p.h.] ASI" (presumably referring to "airspeed indicated"), while those performed by the RAE had been at 400 m.p.h. The two sets of data generally tallied. The next series of tests, using Smiths recorders, would measure upload, sideload and torsion owing to tail forces.

A modified version of the then-current tailplane, featuring nose-balance weights instead of the remote mass-balance, was flown, but proved unacceptable owing to an adverse effect on longitudinal stability. A new larger tailplane was tested on the second Typhoon prototype, P5216, incorporating a 13 per cent increase in area and demonstrating improved longitudinal stability. It reduced the tendency for the type to tighten up in a turn; and, as this was to be a standard fitting for Hawker's next fighter development, the Tempest, it was felt that commonisation with the Typhoon would be beneficial. Furthermore, an improved high-speed aerofoil section could remove some undesirable elevator characteristics which had occurred during the high-speed windtunnel tests. A request was made to repeat these tests with the larger tailplane if they were not already envisaged for the Tempest programme.

When 21 leading lights from Hawker (including Camm, Chaplin and Bill Humble), the RAE's Accident Investigations Branch and "interested" government departments met at the MAP on May 15, 1943, there had been a total of 12 Typhoon tail-related accidents, all but one fatal. Hawker and the RAE were little further ahead as to why, although numerous avenues had been investigated and proven not to be the main cause. To make matters all the more baffling, the aircraft involved in the last four accidents incorporated the latest strengthening modification.

There seemed to be few common factors. Although in the latter cases there had been wing failures, these were generally deemed to be in download and occurring after the primary failure of the rear fuselage. Flying hours relating to the machines involved varied widely, both of pilots and airframes. So did the speeds and altitudes at which the failures had occurred. While there had been a host of investigations into yaw characteristics — particularly when the engine cut (often in negative g) and immediate restart caused a reversal — there was no evidence in any accident of this happening.

Rudders and elevators did not appear to have been subject to rapid oscillation either, although

"All terribly worrying . . ."

IN A LETTER dated February 29, 1976, former Hawker test pilot Philip Lucas (**RIGHT**) replied to former Gloster test pilot John Grierson, who had written to Lucas expressing concern that Kenneth Seth-Smith's contribution to the Typhoon's early development had not been fully acknowledged in Arthur Reed and Roland Beamont's book *Typhoon and Tempest At War* (Ian Allan, 1974). Excerpts from the letter, a copy of which is now in the author's possession, are reproduced below.

TAH ARCHIVE

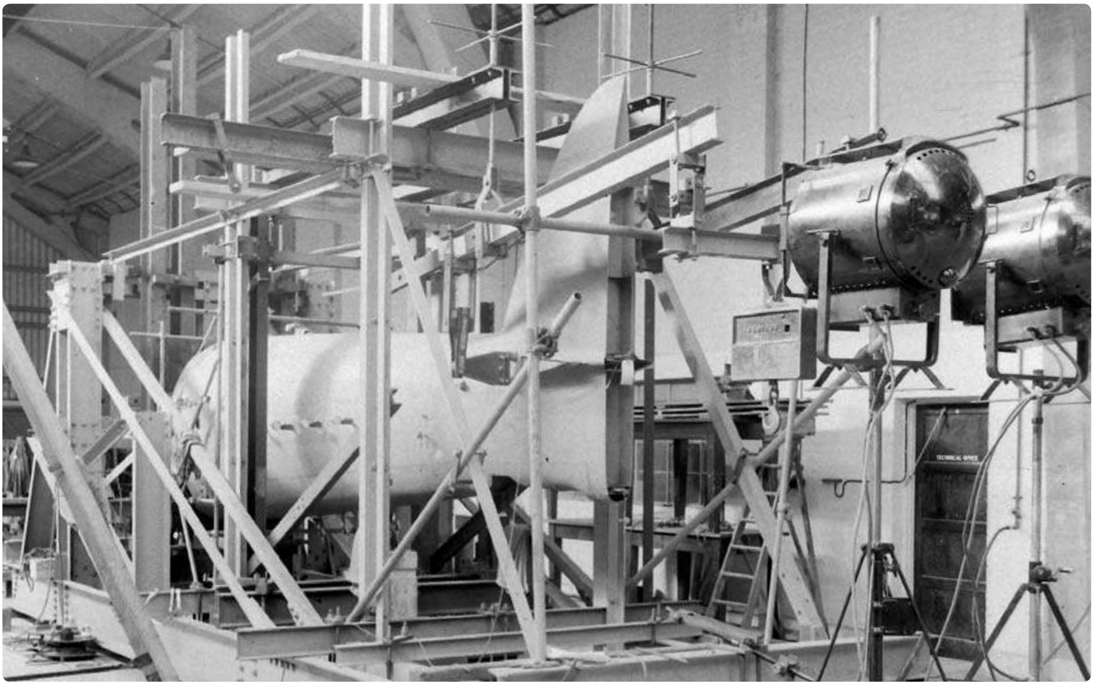
"ALTHOUGH KEN was killed in a Typhoon by the tail unit breaking off, it wasn't until a little while after his death and after many more Typhoons were in service, and consequently more Typhoons involved, that perhaps one of the most intensive accident investigations of the war was mounted by both Hawker and the RAE, which included some pretty hair-raising flight tests at Langley, specifically to try and find out what happened.

Most of this particular flight testing was done by Bill Humble, Merrick Hymans and myself with 'B' [Roland Beamont] playing a fairly small part whilst he was attached to me — not that I am belittling what he did.

As a matter of interest and because of the enormous amount of special instrumentation, which included simultaneous readings of both flight instruments and 'strain gauges' attached to various parts of the empennage and rear end of the fuselage, we designed and installed what I believe was the first automatic camera recorder. In the book *[Typhoon and Tempest]* it said, 'unbelievably we did not carry radio,' but we couldn't, for the equipment took up the whole of the radio compartment. That is why each test was carefully planned and the sequence of tests rigidly adhered to, there being no 'black boxes' at that period of time. I believe too that it was the first time strain gauges had been used in flight.

We had about 28 tail-failures with no survivors. Every crash was recovered and carefully investigated by both Kingston and Farnborough. In each case the whole boxed tail unit broke off just forward of the transport joint, but in each case there was no evidence of buckling or skin-wrinkling, nor anything to connect it with elevator flutter, which of course was the first thing to be suspect. The mass-balance was . . . quite a well-engineered job and not suspect[ed] by RAE. Nor did the flight tests show any sign of structural weakness despite deliberate mishandling under every conceivable flight manœuvre. Nevertheless we introduced quite a few strengthening mods, purely to show that the matter was being taken seriously, but obviously we could not tell the squadrons that we were completely baffled. The surprising thing was the high morale within the squadrons. All terribly worrying because with D-Day within sight, there could be no question of grounding the squadrons.

All the Service engineers were supplied by Langley and each had written instruction from me to report to me personally any incident which might throw some light on the trouble, and it is quite true that the first clue we received was a telephone call from our engineer at Hurn late one night, that a Sergeant Pilot had just complained to him that he had experienced something odd. I told him to ground the aeroplane until I arrived next morning. We interviewed the pilot, who was slightly incoherent or rather inarticulate, and inspected the aeroplane, but could find nothing unusual, so I then flew it with the same result. Nevertheless, we had it dismantled and transported to Farnborough. RAE assembled it again and mechanically vibrated the whole aircraft to find its natural frequencies. All this happened so long ago, but I believe that this was one of the first aircraft to be subjected to this sort of test, although it became common practice during the latter part of the war. Farnborough established a 'node' in the rear end of the fuselage adjacent to the location of the elevator mass-balance, which under certain conditions of flight, set up the forces which broke the fuselage. We altered the weight of the elevator mass-balance by a mere matter of 2lb, and as far as I know we never had another tail failure."



FAST VIA AUTHOR

ABOVE ***The rear section of a Typhoon fuselage undergoing testing at RAE Farnborough. The rear fuselage was initially beefed-up with Mod 256, the fitting of an external steel band around the transport joint; the introduction of Mod 286 (fishplates and internal stiffening) was reckoned to increase the joint strength by another 20 per cent.***

the rudder was frequently found to have moved past its maximum deflection in many cases. Item 2.8 in the minutes states: "Side-loading appears mainly to have caused the fuselage failures in the last four cases, but the primary cause of the accidents is not clear". This was the essence of what Lucas wrote to Grierson all those years later.

Further investigations into yaw in all stages of flight and the effects of compressibility were agreed upon; in the latter case the possibility of a compressibility-stall of the fin, with consequent rapid yaw, and pressure measurement to check for shock-stall at the wing root, were to be made by Hawker. Six weeks later, a similar meeting at Hawker agreed that comprehensive flight trials by the manufacturer and the RAE had not revealed any tailplane loads which could cause fuselage failure.

Progress — and some red herrings

A further strand of the enquiry was opened when aerodynamics specialist Dr Eastman Jacobs of the USA's National Advisory Committee for Aeronautics (NACA) visited Hawker at Claremont on August 11, 1943, to talk to the design team, before going on to Langley to discuss flight experiences. Lucas, Humble and Beamont recounted experiences of pitch and roll instability in high-speed dives up to Mach 0·74 (after which the aircraft would not accelerate) at altitude, during which vapour would form over the wing roots during nose-down oscillation. This was due to compressibility stall and the breakaway of downwash over the tailplane. Jacobs recommended further high-speed tests at altitude and opined that the sudden change in downwash at the point of compressibility stall was the most probable cause of the accidents.

Jacobs's views were again discussed during a review meeting at the RAE on August 18, but the fact that almost all the relevant accidents had been at comparatively low level — below 10,000ft (3,000m) — and at low Mach numbers, seemed to render this view very unlikely. It was also pointed out that to explain failures at or near the transport joint but not at the forward part of the fuselage would require a vertical acceleration of about 40g.

Service engineers were supplied from Langley, and had a written instruction from Lucas to report to him immediately any incident which might throw light on the problem. According to the letter Lucas later sent to Grierson, in the spring or early summer of 1943 Lucas received a late-night call from an engineer at Hurn that a Sergeant Pilot had reported something odd. Lucas ordered that the aircraft be grounded. At Hurn the next morning Lucas "found the pilot slightly incoherent" and after an inspection found nothing unusual. Lucas continues, "I then flew [the aircraft] with the same result [as usual, i.e nothing untoward]. Nevertheless we had the aircraft dismantled and transported to Farnborough. RAE assembled it again and *mechanically vibrated the whole aircraft to find its natural frequencies*" (Author's italics).

This marked the beginning of the end of the problem, as the RAE then began an extensive

TAH ARCHIVE

ABOVE ***A characteristically splendid portrait of Typhoon IB JP682 (with serial blanked off) by renowned aviation photographer Charles E. Brown. By early 1944, with the Allied invasion of occupied Europe imminent, it was imperative that the various modifications to the Typhoon maximised pilots' confidence in it as a fighting machine.***

resonance-test programme on the type. The tests to which Lucas refers in his letter started sometime in the summer. During August 1943 Collar issued Technical Note SME 179, *"Interim Note of Typhoon Elevator Flutter"*, the lead-in summary of which states the following:

"[This] paper contains an analysis of resonance tests on a Typhoon made to determine the mode of fuselage-bending entering into symmetrical elevator flutter. The analysis yields, also the relevant stiffness calculations based on the analysis show that, with the present remote mass-balance system, there remains a significant inertia coupling between the elevator and fuselage motions, and that an additional mass-balance is necessary for the avoidance of elevator flutter".

This interim report, which runs to 13 pages, details the interpreting of the resonance tests, Section 9.2 offering:

"With the present system and mass-balance, flutter sets in at about 400 m.p.h. [640km/h] EAS [equivalent air speed], the frequency being 8·9Hz, and dies out again at 700 m.p.h. [1,130km/h]. Flutter is absent if the present mass-balance is increased by 4¾lb [2·2kg] (with a rigid linkage) or 3¼lb [1·5kg] (with a flexible linkage)".

Section 9.4 continues:

"For the existing system, the most rapid growth of flutter above the critical speed occurs at about 500 m.p.h [800km/h]". These interpretations were of course derived entirely from resonance-test material and theoretical calculation. This work also covered theoretical weights for an elevator-nose-mounted mass-balance, but stability problems with such a system were already becoming known.

The smoking gun?

A full report, entitled *"Resonance Tests of a Typhoon Aeroplane"*, was issued as SME 197 in November 1943. The methodology for the test involved the elastic suspension of a complete airframe, which rested on its mainwheels with tyres very soft, the rear fuselage being suspended elastically, the whole being in horizontal flight attitude.

A Mullard electromagnetic pick-up worked on the seismic principle, the outer case being held firmly against the vibrating station. An internal mass, spring-controlled and suitably damped, remains almost stationary in space when the unit is subjected to high-frequency vibration. The relative movement between the mass and the case generates a small voltage which is amplified and fed to an oscillograph, appearing on the screen as a wave trace. Thus, vibration readings may be taken at stations on the fuselage centreline and on the front and rear wing-spars.

The airframe was vibrated by a simple rotating mass with adjustable degrees of imbalance and was mounted to give a simple harmonic force having vertical and horizontal components. The unit was clamped to the hydromatic gear unit in the propeller hub and was driven by a variable-speed electric motor. The applied force was small, less than would have been required if mechanical recording had been used.

Typhoon propeller & tailplane Mods, September 1944

ON SEPTEMBER 25, 1944, a memorandum was issued clarifying the state of Typhoon mods as follows:

Propeller	Tailplane	Inertia weight	Mass balance	Relevant Mods	Remarks
Three-bladed	Original	—	6lb (2·7kg)	—	Original
Three-bladed	Original	16lb (7·25kg)	8lb (3·6kg)	Mod No 353	Current
Three-bladed	Large	16lb (7·25kg)	6lb (2·7kg)	Mods Nos 354 & 395	Current
Four-bladed	Large	16lb (7·25kg)	6lb (2·7kg)	Mods Nos 339 & 354	All present production aircraft

The frequency range providing data for flutter calculations was 0–18Hz. There were two major resonances at 9·3Hz and 13·2Hz. At 9·3Hz the nose and tail of the aircraft were moving up, the outer wings were moving down, while the centre section remained almost still. At 13·2Hz the nose, tail and wings were moving upwards while the centre section moved downwards. The node at 13·2Hz, just forward of the elevator mass-balance in the static test, implied that in flight the mass-balance weight would be largely ineffective. Furthermore, when in flight the wing motion was strongly damped, the node would move fore and aft. As Lucas said more than 30 years later in his letter: "Farnborough established a 'node' in the rear end of the fuselage adjacent to the location of the elevator mass-balance, which, under certain conditions of flight, set up the forces which broke the fuselage".

This was the information which had been sought for a year, and which in due course led to alterations to the mass-balance weight and the addition of an inertia-weight at the base of the control column. Arriving at these modifications was by no means swift, however, as the information had to be extensively checked and test-flown, arriving as it did in the midst of a number of other modifications to the tailplane, including standardisation of the larger unit and the introduction of a four-bladed propeller.

Mod 353: the "key fix"

The squadrons still had to deal with the ongoing maintenance problems thrown up by this host of changes, some 2,400 Typhoons having been delivered by this time. Dated January 6, 1944, Mod 353, *"Elevator Mass Balance Modified & Inertia Weight Introduced"*, was the "key fix", calling for an inertia-weight of 16lb (7·25kg) at the control-column base and a mass balance of 8lb (3·6kg).

On February 9, 1944, the new, larger tailplane was introduced (for which the mass-balance weight was reduced), while the four-bladed propeller was increasingly becoming available. Another modification, Mod 395, became available from April 29 to "stabilise the tailplane" further. This involved adding weights to the nose of the elevators on the large tailplane, when used in conjunction with a three-bladed propeller. Then in early June changes were made to improve the interchangeability of tailplanes (see panel above).

That lot must have been more than enough to tax the resources of the Maintenance Units, let alone the squadron engineers and fitters! And all this was being done while a ferocious battle was raging through western Europe, with Typhoon squadrons constantly on call to support armour and infantry and destroy communications.

In his letter to John Grierson more than 30 years later, Philip Lucas wrote that there were no more accidents after the modifications were made. He was right insofar as accidents attributed to tail-failure for the reasons unearthed by the RAE ceased; but, until the Typhoon's frontline service career ended, squadron aircraft were subjected to extremely harsh treatment in combat and there were further structural failures, generally attributed to unrepaired combat damage or heavy overstressing by the pilots, often when carrying full loads of bombs and/or rocket projectiles.

A letter dated June 14, 1944, from Mr R. Hain Taylor, on behalf of the Director of the RAE (Sir William Farren), to the Air Officer Commanding, Bentley Priory, concerning a Typhoon at Holmsley South which had suffered skin distortion to the wings, is enlightening: "The trace for this aircraft . . . shows heavy pull-outs, the most pronounced of which is 8 to 8·25g at around 450 m.p.h. [725km/h]. Others peak at 7·25g at 420 m.p.h. [670km/h] and 7g at 360 m.p.h. [580km/h]. It is understood that an aircraft had been inspected which had deep buckles at the change of dihedral, our representative being informed that the wing commander 'regularly buckles his wings on operational flying'". Figures relating to Typhoon MN141 show one isolated peak of 10·25g at 460 m.p.h. (740km/h). There is no reply on the file!

The Typhoon would not have proved to be such a potent weapon, nor formed the basis of the mighty Tempest and Fury/Sea Fury — arguably the finest single-piston-engined fighter of all — without the extraordinary skill and perseverance of those at the RAE in support of the Hawker design team led by Sydney Camm.

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