THE SAGA OF THE F-15 WING TIP

SUMMARY

Early during the F-15 flight test program, a limit buffet condition well within the operational flight envelope (M~0.9, 30K ft, 4-5 g's) was discovered. It was identified early on to be associated with shock induced flow separation on the outer wing panels. Suggestions were made that to solve the problem, a simple planform modification to the wing tips—removing surface area—would be appropriate. The suggestion was ignored until modifications were made to solve an apparent loads problem which existed at a different flight condition. These two problems (buffet and loads) were solved by "clipping" the wing tips (removing about 9 square feet of surface area), but it took months of testing, both in the wind tunnel and in flight, after the time of the initial suggestion before the modification was incorporated and evaluated.

The following narrative chronicles the key events in the F-15 flight history as it relates to the wing planform shape.

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The F-15 buffet problem was discovered with F#1, Flight 26 on 25 August 1972 with Pete Garrison, pilot. The buffet was described as "hard, pounding buffet" so heavy that the cockpit instrument were unreadable.[1] It occurred in a very small portion of the flight envelope at about 0.9 Mach, about 4.5 gs, 30,000 ft altitude. Although limited MCAIR investigations were conducted during the next three or four weeks, it wasn't until the AFPE de-briefing of 4 Oct 72[2] that much excitement was generated within MCAIR.

By 10 Oct 72, strain gage data became available—these data indicated that the empennage was *not* the cause of the problem but that the heavy buffet correlated with major, large amplitude load oscillations on the outboard portions of the wings.[3] Additional strain gage data were obtained with F#1, Flights 43, 48, 51, 66, 68, and 69 and transmitted to St. Louis for in-depth analyses. These data reinforced the conclusions this writer had made on 10 October. In addition to the airframe buffet, a slight pitch-up tendency which had been noted by the pilots was found to occur simultaneous with the onset of the heavy wing buffet.[4]

For the next several months, we (at Edwards) concentrated on other problems including speedbrake buffet, cross-wind landing, and supersonic directional characteristics. But in February 1973, the buffet program was restarted with additional instrumentation (wing tip acceleration, wing surface pressures outboard of the flap/aileron intersection, empennage dynamic loads <even though the buffet characteristics had all the earmarks of wing shock induced flow separation>, and surface tufts for flow visualization.[5] The data obtained with this additional instrumentation again revealed no other contributor than outer wing panel load oscillations.[6] (Tuft photos revealed nothing of note).

An extensive wind tunnel test program was planned in July 1973 to evaluate about every configuration that the St. Louis management people could dream up—wing LE snags and notches, vortilons, strakes, fences, etc. in hopes of finding some "magic" to solve the problem.[7]

While the wind tunnel testing was in progress, beginning in August 1973, TF#1 performed some buffet tests to evaluate more hoped-for magic (up ailerons/flaps) and to presumably provide a better understanding of the phenomenon (St. Louis and Edwards aerodynamicists did not agree with each other on the nature of the problem.[8,9,10]).

St. Louis management was becoming more desperate by September 1973 and added wind tunnel test configuration changes including horizontal tail anhedral, decreased horizontal tail span, etc., etc.[11]

On 10 Sep 73, this writer suggested to Edwards Technology Integration supervision that we fly one of the airplanes with the outer wing panel removed.[12] This suggestion was not well received—MCAIR was very proud of the 1969 design effort in selecting the F-15 wing planform; this effort involved hundreds of wings tested in wind tunnels and a Computer Aided Design Evaluation (CADE) process to help select the winner. A suggestion to change the wing was tantamount to heresy!

In late September 1973, at a Management Review at Edwards, buffet investigations were shifted to F#9. **In addition, at this meeting, the St. Louis Loads Engineer offered his conclusion that the heavy**

buffet was coming from the wing instead of the empennage! based on the analysis of data from F#4. **(This writer commented sarcastically, "How about that!").**[13]

At meetings in St. Louis in early October 1973, the F#9 test program was discussed, and it was noted that most F#9 tests would be performed in St. Louis. These tests would include such items as wing fences, gun bump fences, wing LE droop, stall strips, wing contour changes, gun bump strakes, vortex generators, fuselage strakes, etc. At this time, I reiterated by telecon to St. Louis management that I felt the only big improvement would realistically be due to such things as a lower aspect ratio, higher taper ratio (tip chord/root chord), and higher sweep—typical solutions to shock induced separation**. I added the query, "Why not clip the tips off?"**[14]

After a few St. Louis flights in St. Louis with F#9, others in St. Louis (not Aero) were beginning to conclude that the problem was due to shock induced separation and that it appeared to be exciting the fuselage first bending mode at 8.5 to 10 Hz.[15]

On 29 Nov 73, St. Louis management reported a "break through" on the buffet—a wing fence and a gun bump strake appeared to have eliminated the heavy, pounding buffet (three flights by Plummer on F#9). Later this was substantiated by flights by Krings and Dobronski.[16,17] However, further testing to refine the configuration continued on. But in late February 1974, a buffet improvement configuration was selected: wing fences and gun bump fences (this writer's records don't define the exact configuration).

In early March 1974, a decision was made (*very quietly*) to clip the wing tips from F#4 to investigate a perceived loads problem—high bending moments on the outer wing panes at M=1.02, 20K. And there was fear that the "final" selected buffet improvement modifications would make things worse.[18,19] It may very likely be that the Air Force was not made aware of this decision until after the fact.

So, at the direction of a VP who had a *structural* background, the wing tips of F#4 were clipped off (the shape defined by Bob Grogan, a Design Engineer assigned to the Edwards test program so as to retain the navigation lights**). This circumcision occurred about seven months and many flight tests/wind tunnel tests after the same suggestion had been made by the Edwards *aerodynamics* Project Engineer—but for different reasons.**

In mid-March 1974, F#4 made Flights 153 and 155 with Garrison as the pilot to investigate the impact of the clipped tips on the heavy buffet.[20,21] This writer's report of 18 Mar 74 in regard to the clipped tip effects notes that:

"<u>Buffet.</u> Although it has long been anticipated that clipping the wing tips would improve the limiting buffet situations, it may be that the clipped tips have completely eliminated the problem…"[22]

Charlie Plummer, following his F#4 Flight 157 rated the various buffet configurations he had flown on a scale of 3 to 10, with 10 being the best and 3 corresponding to the unmodified airplane:[23]

- Big fence and strake of last fall—10
- Final fence and strake—8
- Mounting stubs—7
- Clipped tips—5-7
- Basic—3

Meanwhile, the Air Force had flown F#9 with the final fence and strake and concluded that the configuration should be incorporated into production unless:

- Performance degradation is more than "slight."
- Difficulties exist above 5.8 gs (the highest load factor they had flown to).
- Effects of the clipped tips/cost considerations out weigh the strake/fence advantages.[24]

As it turned out, performance degradation (drag) and costs were considerable. Sometime in late April 1974, it was decided that the clipped tips would be incorporated into production, and the fence/strake configuration would be dropped.[25] During a trip to St. Louis on 8 May 74, this writer was admonished for referring to the wing tip configuration as "clipped"—from that day forward, they were referred to as "raked" wing tips per St. Louis management instruction.

In early June 1974, the Air Force flew the “raked” tip configuration and were completely satisfied with the configuration’s buffet characteristics.

Thus ended the F-15 wing tip saga.

REFERENCES

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