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UNIVERSITY OF SOUTHERN CALIFORNIA

SCHOOL OF ENGINEERING

WING-TAIL INTERFERENCE EXPERIMENTS

AT SUPERSONIC SPEEDS

(BUWEPS Problem Assignment No. 1-32-21)

BY

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USC Engineering Center

C O P Y N O ______

AERODYNAMIC TEST LABORATORY, NMC

OPERATED BY THE UNIVERSITY OF SOUTHERN CALIFORNIA

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APPROVED BY:

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BACKGROUND

Problem Assignment 1-32-21 (Formerly designated TED-NMC AD 3076) was initiated by the Bureau of Naval Weapons and assigned to the Aerodynamic Test Laboratory* in January 1960 for the purpose of establishing a set of experimental data which could be used to evaluate the utility of prevailing aerodynamic theory as applied to the design of supersonic missile configurations. Emphasis was to be placed on the study of aerodynamic interference parameters among the elemental low aspect ratio wing-body-tail combinations.

The assignment gave the ATL responsibility for the general design of the experiments, their execution, and the correlation of results with appropriate theories. All work was to be carried out on a low priority basis, such that it would not interfere with regularly scheduled missile and airplane development programs at the laboratory.

DESCRIPTION OF PROGRAM

The test program that was developed to satisfy the objectives of the assignment was conceived in three phases. The first two phases were to devote primary attention to the measurement of wing-tail interference effects in the Mach number range 1.6 - 3.5. These tests would complement the work described by Carroll in Reference 1, in which the mutual interference effects of a variety of body-wing combinations were investigated experimentally in the Mach number 2.0 - 4.5 range and the results correlated with the analytical techniques described in Reference 2. The parameters which emerge from the analysis of Reference 2 to

* The Aerodynamic Test Laboratory (ATL) at the U. S. Naval Missile Center, Point Mugu, California, has been operated by the University of Southern California Engineering Center, under contract to the Navy, since completion of the ATL facilities in 1951.

govern the effects of wing-tail interference are wing and tail lift coefficients, the aspect ratio and taper ratio of the tail, the ratio of body diameter to tail span, and the location of the wing vortex relative to the tail center of lift. The lateral vortex location is determined by the wing plan form parameters of aspect ratio, taper ratio, and the span to body-diameter ratio, while the vertical location is primarily determined by the angle of attack and distance from the wing trailing edge to the tail center of lift

PHASE I TESTS

A family of models designed to provide a systematic variation of all of these parameters was fabricated in the ATL shops and tested during the period 27 May - 15 June 1960. Figures 1 and 2 are sketches of the configurations investigated. Both the wing and tail incidence angles were fixed at zero degrees. The tail interference effects were derived from an evaluation of the differences between the lift and moment measurements of the various body, body-wing and body-tail configurations and also the complete body-wing-tail configurations. Evaluations of this type are necessarily tedious and limited in accuracy because they involve small differences between relatively large numbers, and errors in the primary measurements are correspondingly magnified for the effect under investigation. None the less, some fairly encouraging results were achieved.

Figures 3 through 8 are summary plots of experimental-vs-estimated lift-curve slopes for all of the combinations investigated Each point was evaluated by taking the slope of the lift curve at $\alpha = 0$ obtained from the best fit of lift coefficients measured in the range $-10^{\circ} < \alpha < 10^{\circ}$. The body lift slope, taken as twice the body cross-sectional area, was substracted from these values and the result multiplied by $\sqrt{M^2-1}$ in order to normalize first order Mach number effects and focus attention on the performance of the lifting surfaces and their associated interference factors. It should be noted that while the lift from the body alone was removed by this process, the lift on the body induced by the wing was retained. All estimated values of lift-curve slope were computed with the proceedures prescribed in Reference 2; these procedures are essentially based on linearized supersonic aerodynamic theory.

Figures 3 and 4 show some significant differences between estimated and measured lift slopes for the wing-body and tail-body combinations. In general the slopes are overestimated at Mach number 3 and underestimated at Mach number 1.6. This, at least in part, may be attributed to the fact that the body-alone lift was underestimated due to neglecting the nose lift carryover on the after-body at high Mach numbers. This defect would be expected to be more pronounced in the case of the series 1 combinations rather than the series 2 combinations, where the areas of the lifting surfaces relative to the body cross-sectional area are much larger.

Figures 5 - 8 show similar results for the wing-body-tail combinations. Each figure has two plots, one without the wing-tail interference factor included in the calculation and the other with this factor included. It is seen, in comparing the plots, that the wing-tail interference theory employed was successful, for most cases, in narrowing the deviation from agreement with the experimental data to about 10%.

PHASE 2 AND PHASE 3 TESTS

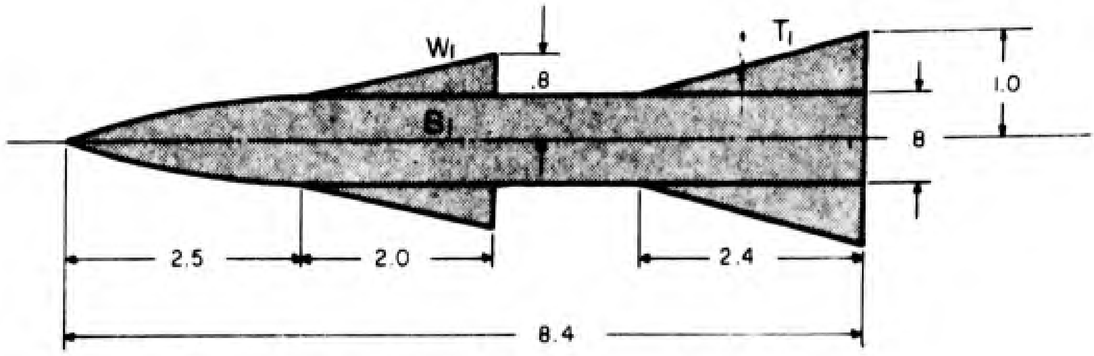
Phases Two and Three of the program never advanced beyond preliminary planning because of the lack of sufficient priority relative to other programs assigned to the laboratory up to the time when operations were suspended in June 1962. In Phase Two it was planned to make more accurate and detailed tail load measurements on a half-span wall-mounted model with both the wing and tail panels suspended on independent balance elements Measurements would be extended to include wing incidence effects with provision for remotely inclining the wings up to 30°. Variation in angle of attack was also to be provided. Wing and tail configurations were to be selected from those tested in Phase 1 such as to achieve a maximum variation of wing vortex strength and lateral displacement over a given tail configuration. Thus, the arrangement would have afforded a direct measure of the relationship between induced tail load and wing lift and would circumvent most of the difficulties and shortcomings found in Phase 1 testing, namely the indirect measure of effects of interest and the uncertainty in the body lift values. With the wall-mounted model the body would not be suspended on the balance and there would have been no need to estimate the body's lift contribution. Another benefit of the wall-mounted model is that a root bending moment element on the tail panel balance would give a direct measure of the lateral location of the wing vortex.

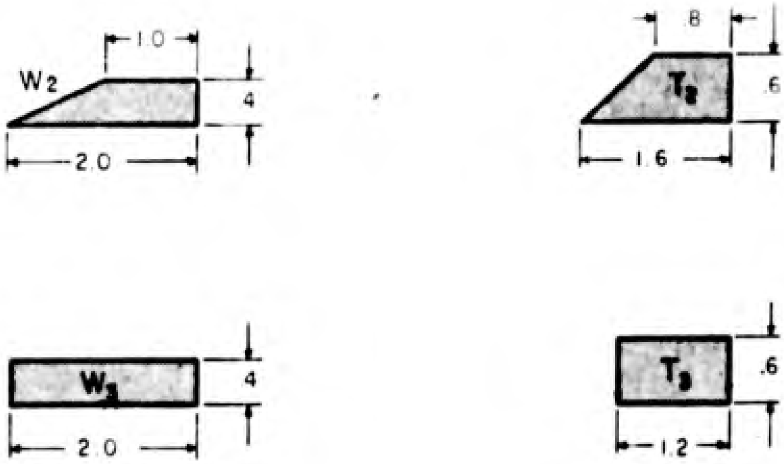
Phase Three of the program would have extended Phase 1 and Phase 2 testing to Mach number 6 with the ATL's new Mach number 4 0 - 6 0 wind tunnel, which became operational for testing in October 1961. It was planned to investigate the wing-body mutual interference effects as well as wing-tail interference and thus extend the experimental work of Reference 1 to Mach number 6.0, however these tests were never accomplished.

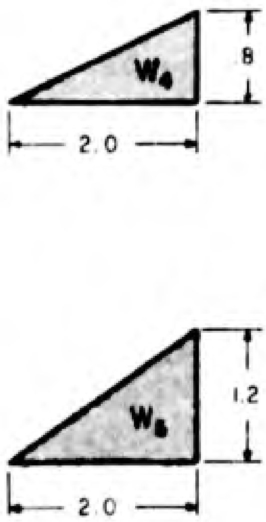
REFERENCES

1. Carroll, James B., "Tests of Wing-Body Combinations at Mach Numbers Between 2.0 and 4.5", United Aircraft Corporation Report SR-0888-4, 1959.

2. Pitts, William C., Nielsen, Jack N., and Kaattari, George E., "Lift and Center of Pressure of Wing-Body-Tail Combinations at Subsonic, Transonic and Supersonic Speeds", NASA Report 1307, 1957.



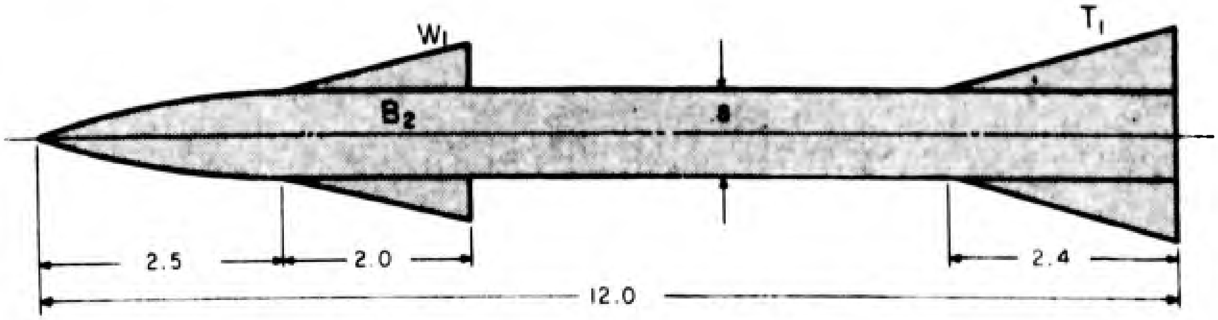


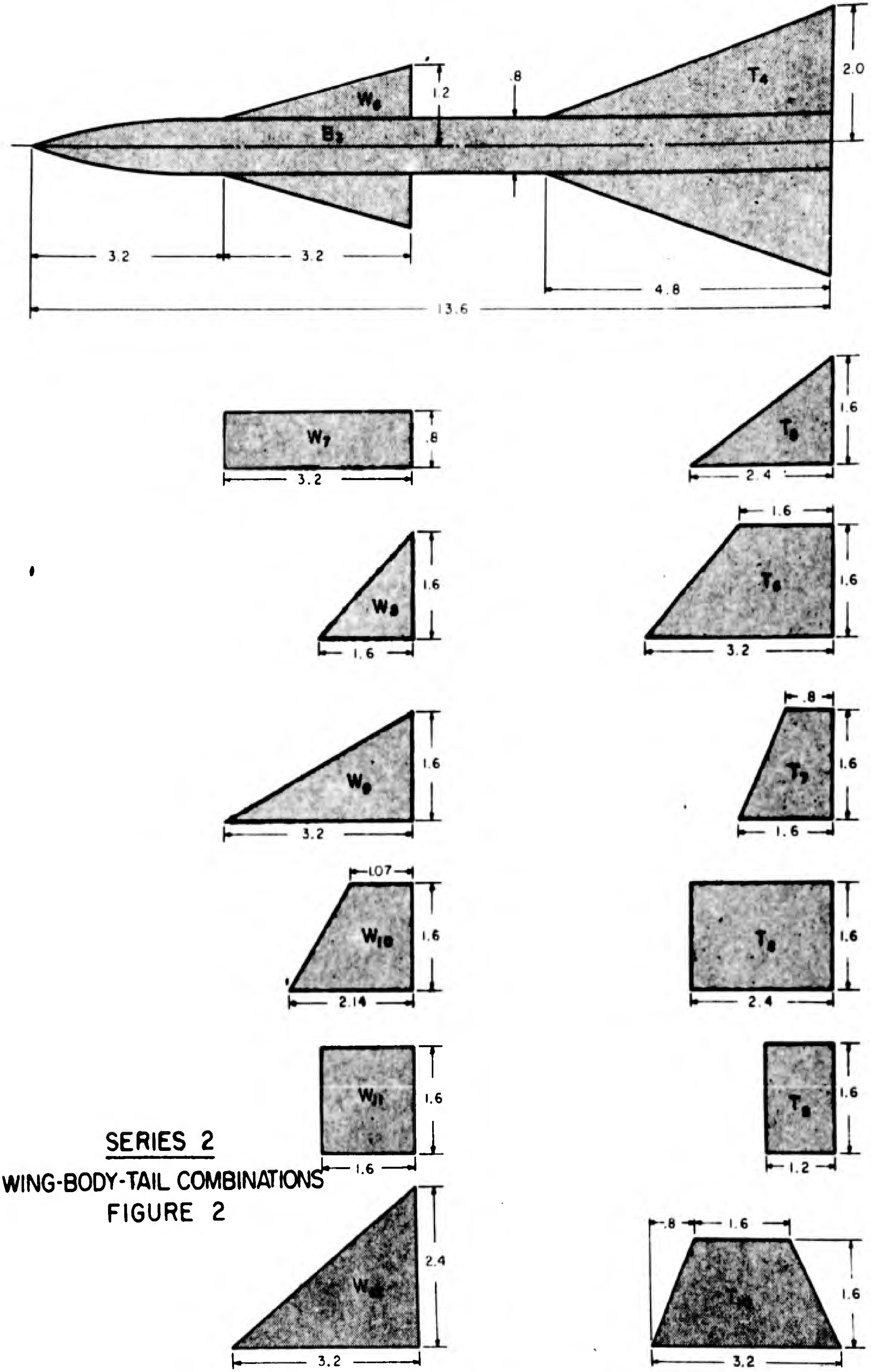


SERIES I

WING-BODY-TAIL COMBINATIONS

FIGURE I





SERIES 2

WING-BODY-TAIL COMBINATIONS

FIGURE 2

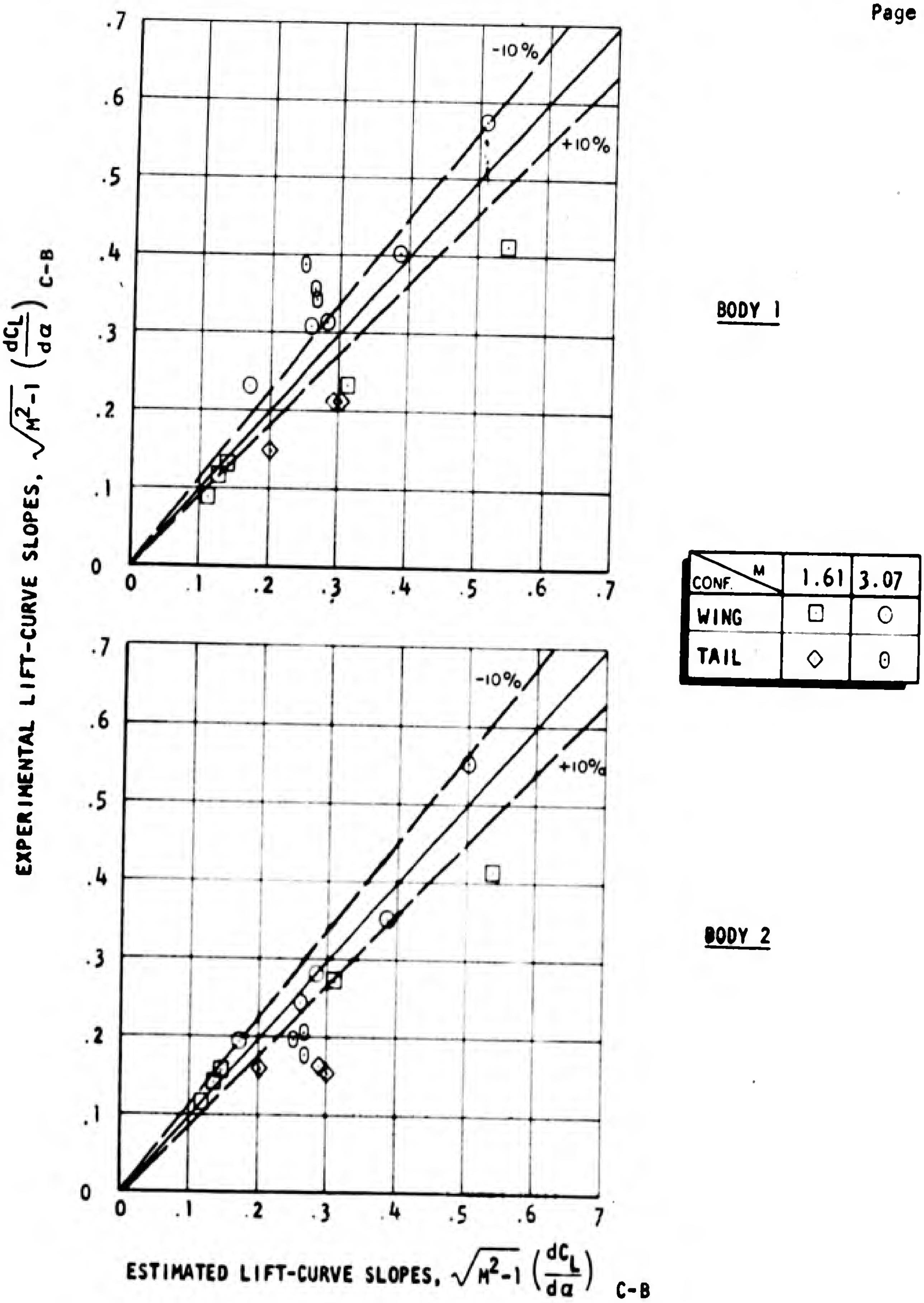


FIGURE 3, EXPERIMENTAL VS ESTIMATED LIFT-CURVE SLOPES FOR SERIES 1 WING-BODY AND TAIL-BODY COMBINATIONS.

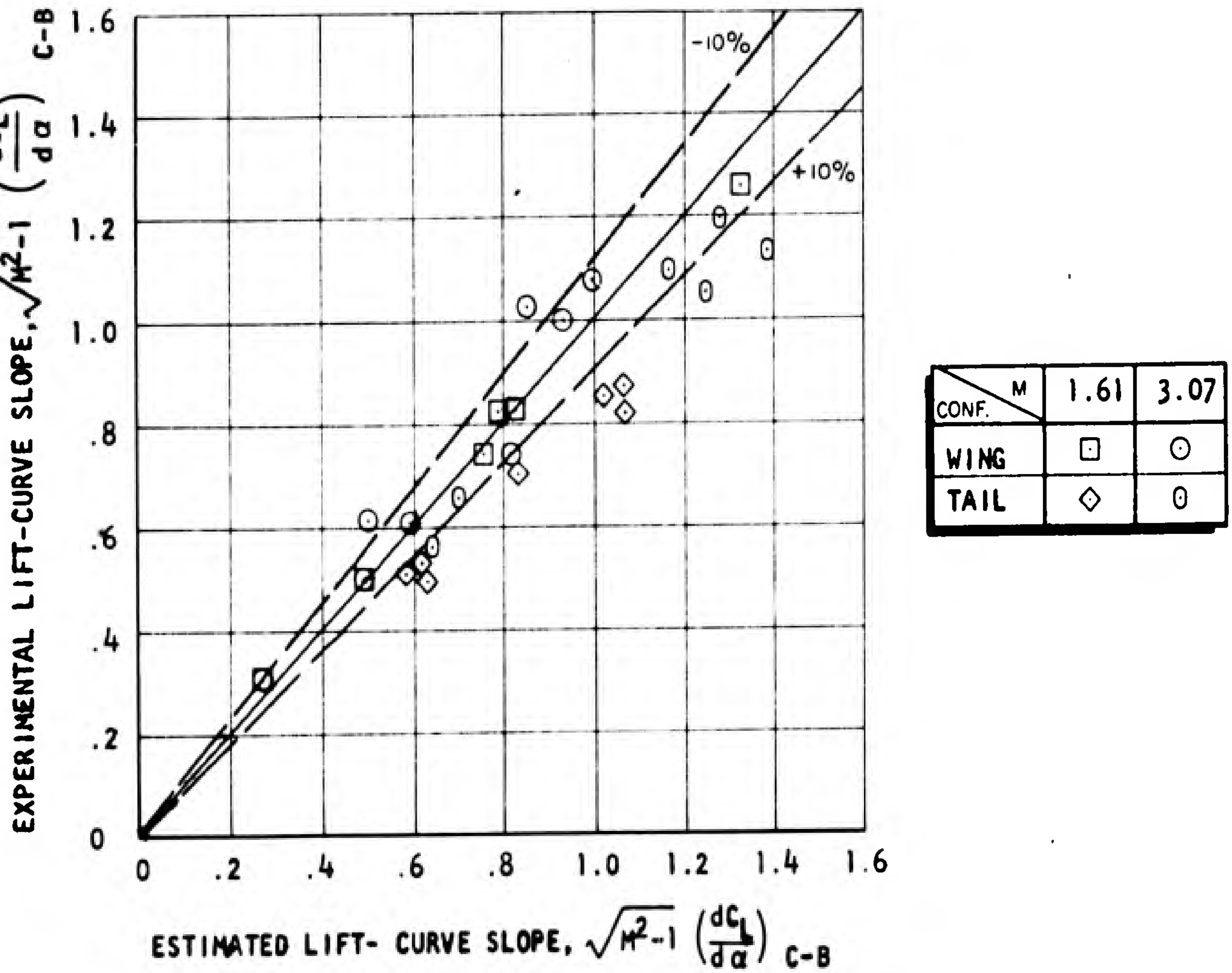


FIGURE 4, EXPERIMENTAL VS ESTIMATED LIFT-CURVE SLOPES
FOR
SERIES 2 WING-BODY AND TAIL-BODY COMBINATIONS.

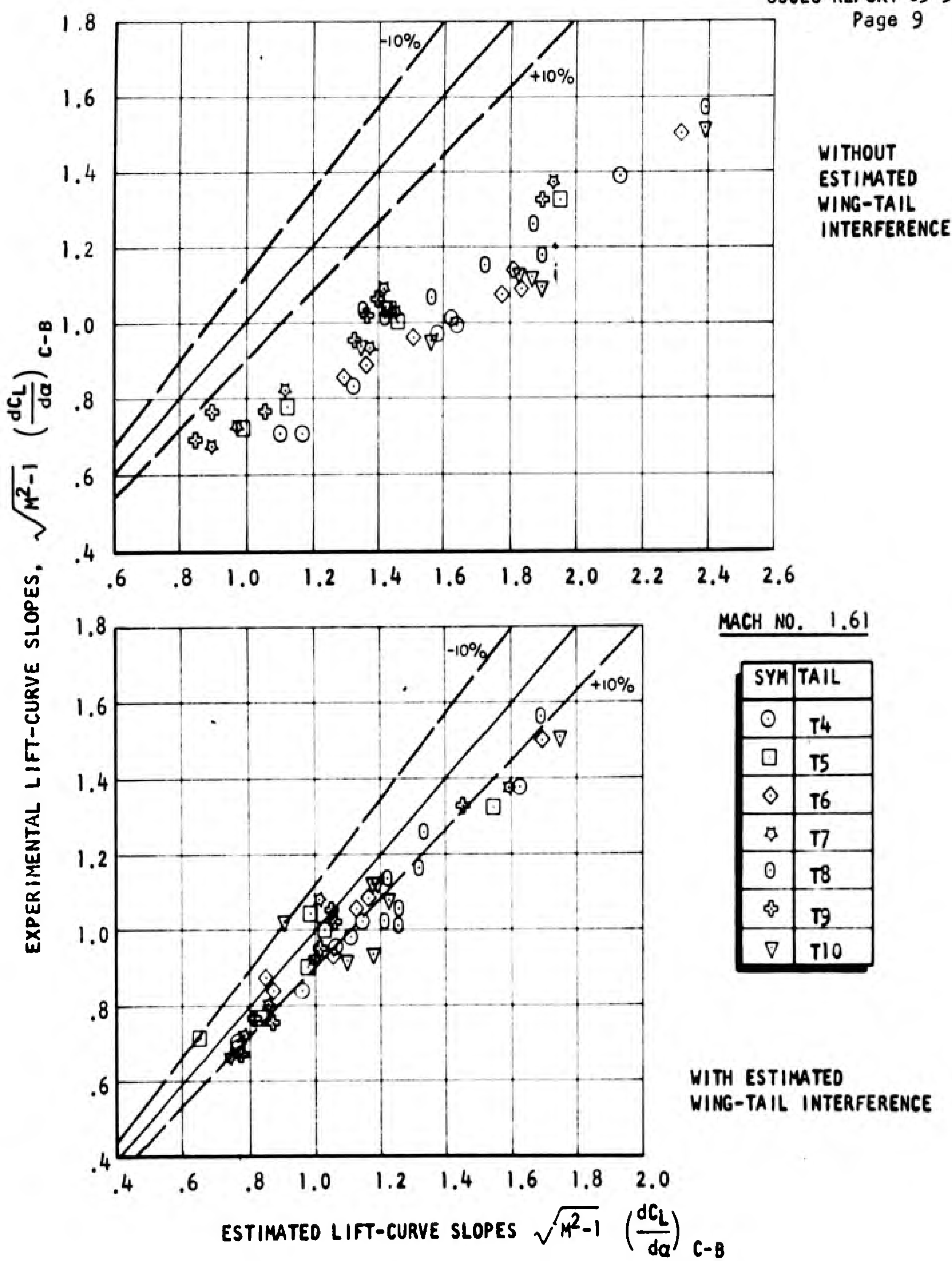


FIGURE 5, EXPERIMENTAL VS ESTIMATED LIFT-CURVE SLOPES FOR SERIES 2 WING-BODY-TAIL COMBINATIONS AT MACH NO. 1.61

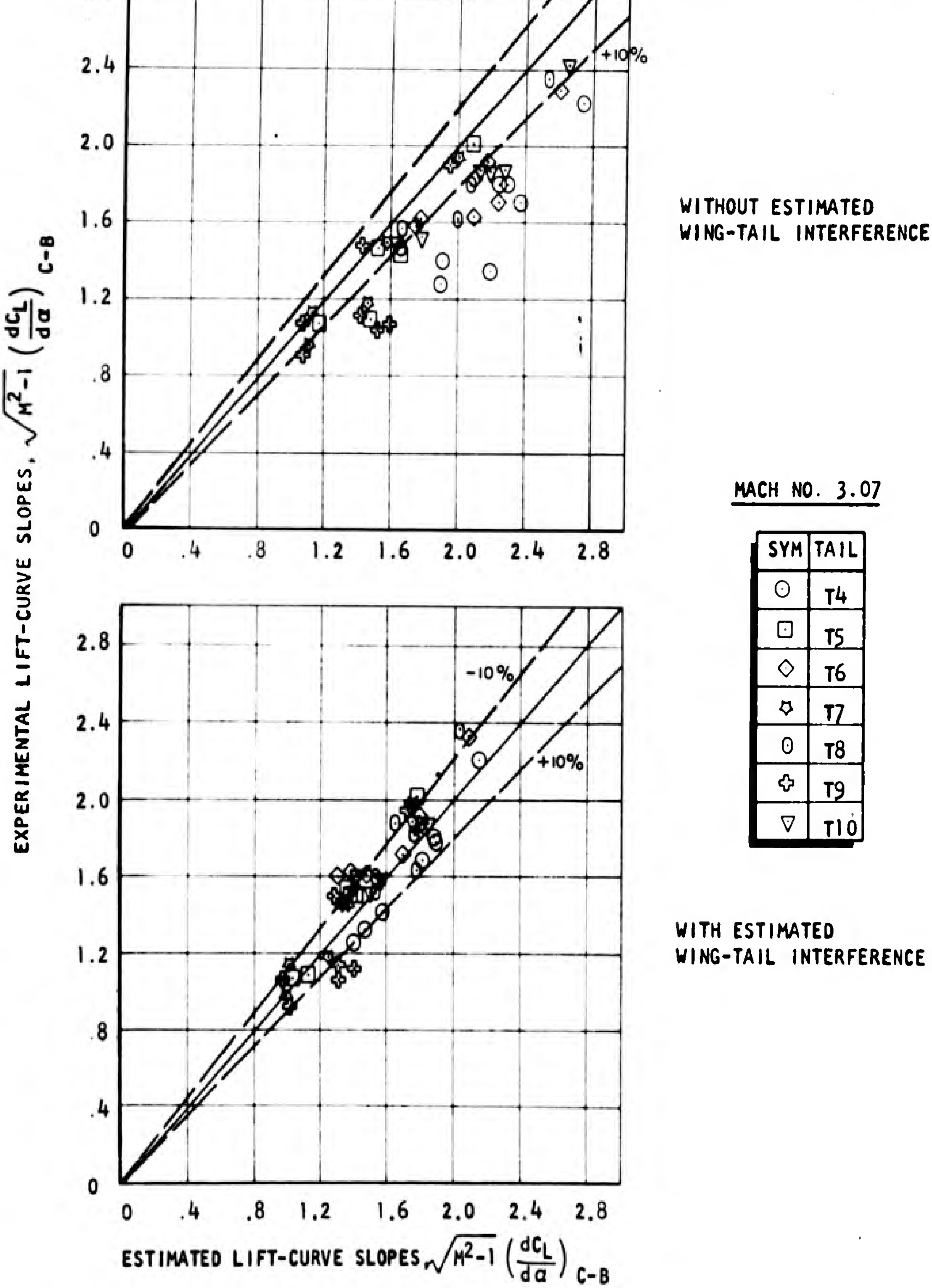


FIGURE 6, EXPERIMENTAL VS ESTIMATED LIFT-CURVE SLOPES FOR SERIES 2 WING-BODY-TAIL COMBINATIONS AT MACH NO. 3.07

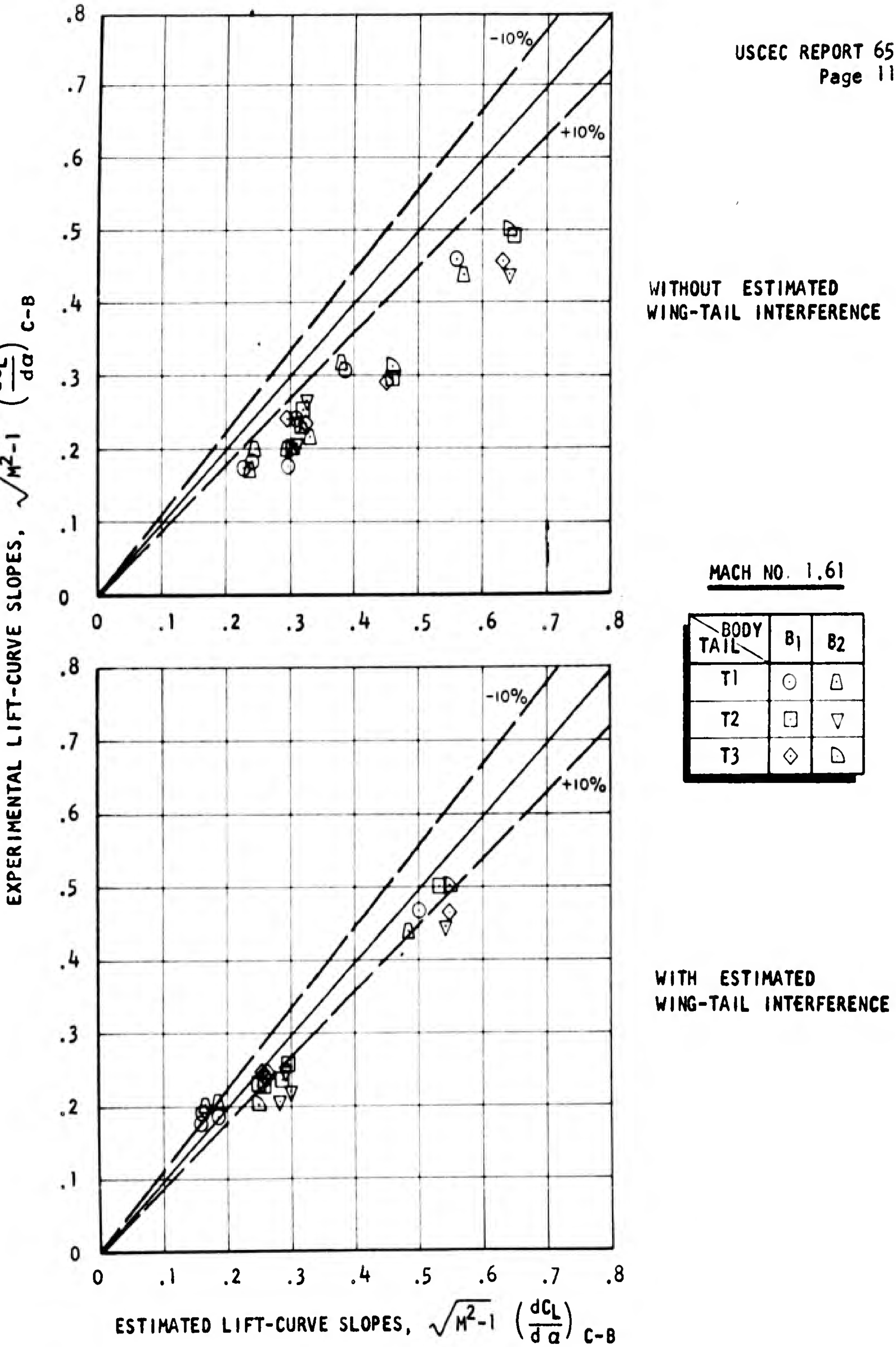
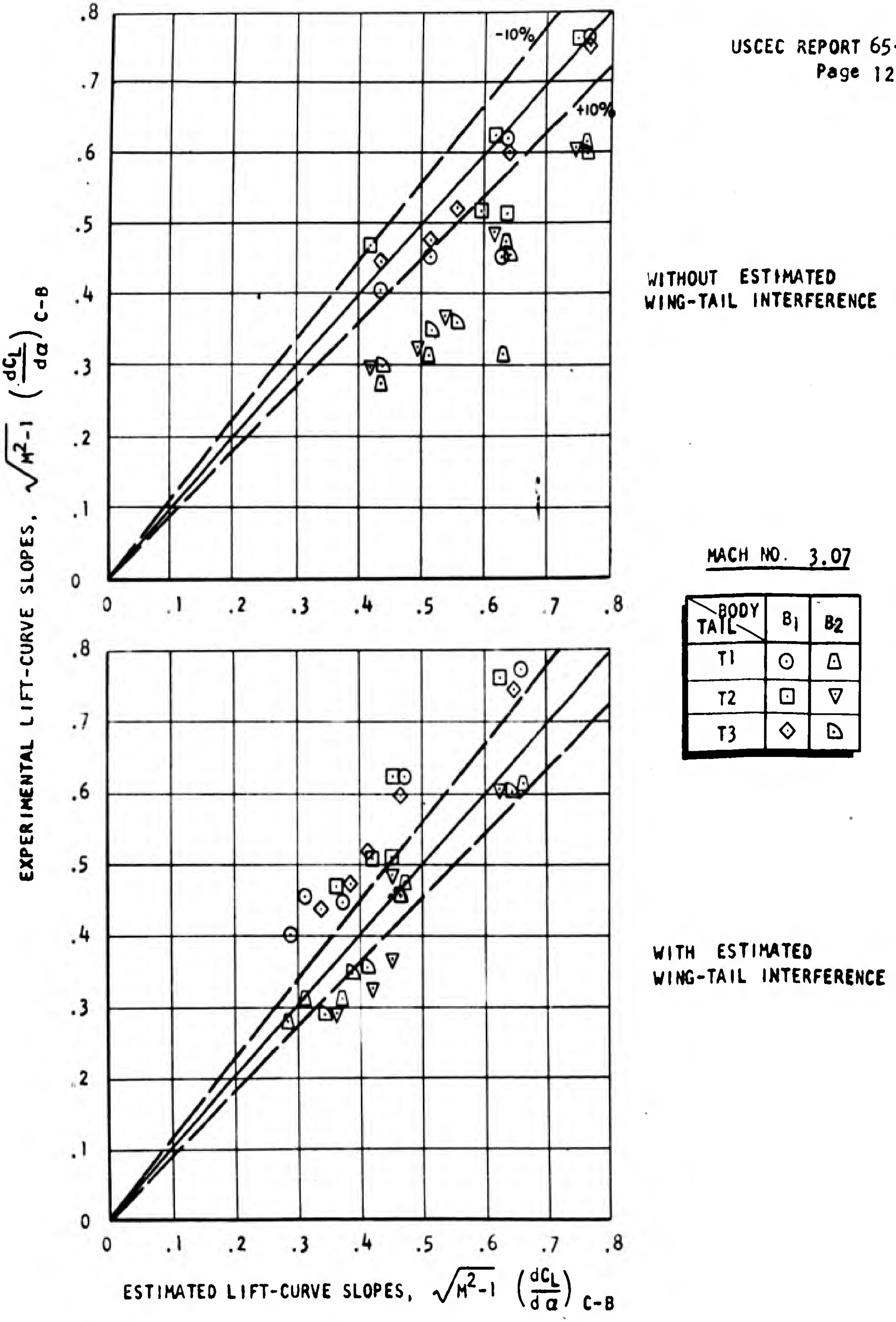


FIGURE 7, EXPERIMENTAL VS ESTIMATED LIFT-CURVE SLOPES FOR SERIES 1 WING-BODY-TAIL COMBINATIONS AT MACH NO. 1.61



TAIL \ BODY	B_1	B_2
T1	⊙	⏢
T2	⊡	▽
T3	◇	◗

FIGURE 8, EXPERIMENTAL VS ESTIMATED LIFT-CURVE SLOPES FOR SERIES 1 WING-BODY-TAIL COMBINATIONS AT MACH NO. 3.07

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