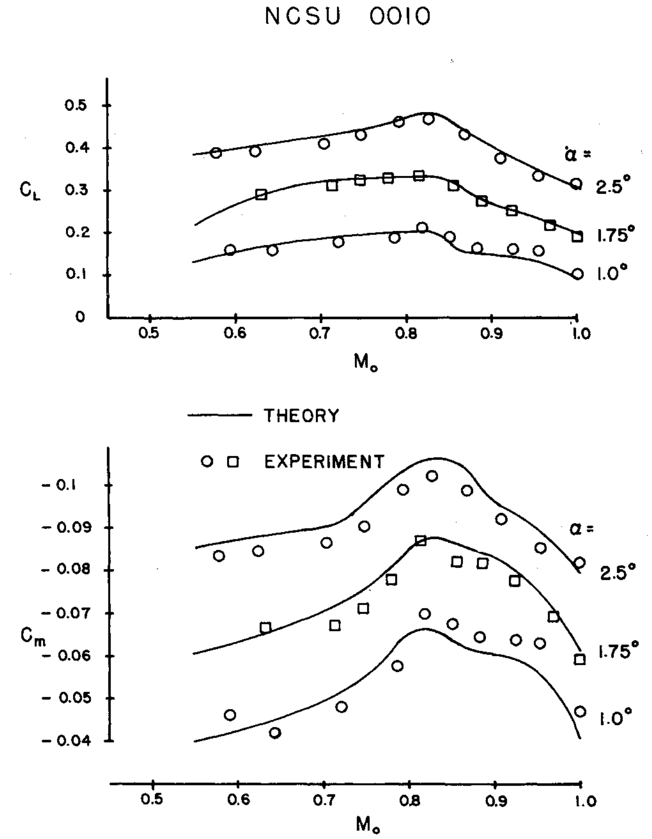


**Fig. 3 Summary of results for one airfoil.**

larger than 1%. The model consumed about 3.5% of the tunnel cross-sectional area at $\alpha = 0$ and the two slotted walls were 50% open. It was felt that under these conditions wall interference corrections were not necessary and none were made. Model angle of attack was limited to about 4° because increased blockage then limited the attainable Mach number. Generally, the agreement between prediction and experiment deteriorated as $\alpha$ increased. This is thought to be due to the increasing importance of boundary-layer displacement effects associated with the adverse pressure gradient over the rear portions of the airfoil at higher angles of attack. The simple vortex distribution scheme used to compute the $M = 0$ distribution of course does not permit this displacement effect to be considered as does the more inclusive method of Ref. 5.

The success of the simple prediction scheme offers sufficient incentive to warrant the effort to include a better vortex distribution method and a more accurate description of the shock pressure rise in the calculation procedure. If these modifications improve the agreement between prediction and experiment without excessive increases in computer time, it would appear reasonable to attempt to include a more analytical version of the method of Ref. 7 as well.

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# Correlation of Wing-Body Combination Lift Data

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WHEN a wing is added to a body at low angles of attack, there are mutual interference effects present between the components that makes the lift of the wing-body combination greater than the sum of the lift of the individual components. These interference effects are 1) the effect of the body upwash or cross flow on the local angle of attack of the wing; 2) the effect of local body-flow parameters such as Mach number and dynamic pressure on the wing characteristics; 3) the effect of the lift carryover from the wing onto the body; 4) the effect of wing upwash on the body ahead of the wing; 5) the effect of the wing lifting vortices on the body behind the wing.

These mutual interference effects on the wing-body lift are generally small for configurations with body diameter to wing span ratios, $d/b$, less than 0.1 (typical of high aspect ratio aircraft). For $d/b$ ratios greater than 0.1, typical of low aspect ratio aircraft and missiles, the interference effects are significant and should be accounted for in order to properly determine the lift characteristics of particular wing-body configurations. The method of Pitts, Nielsen, and Kaattari[1] considers the aforementioned five interference effects and predicts the lift characteristics of wing-body combinations with an accuracy of ±10%. Their method suggests that the wing-body lift curve slope at all

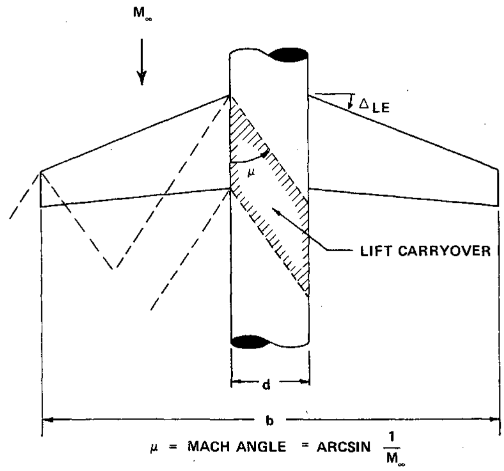


**Fig. 1 Sketch of wing-body showing lift carryover region and wing-body parameters.**

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Mach numbers can be expressed as

Insert $$(C_{L\alpha})_{WB} = F(C_{L\alpha})_W \quad (1)$$

where $(C_L\ )_{WB}$ and $(C_L\ )_W$ are the lift curve slope of the wing-body and wing, respectively, at zero angle of attack (both based upon the exposed planform area of the wing, $S_e$) and $F$ is a wing-body lift interference factor. The $F$ factor is considered a function of Mach number and the wing-body geometry.

The theory[1] indicates that

Insert cut 44′ $$F = F(d/b, M) \quad (2)$$

with *weak* dependence on wing aspect ratio, taper ratio and sweep. The location of the wing on the body influences $F$ primarily through the interference effect number 3 mentioned earlier. This life carryover is shown on Fig. 1 and can be a significant part of the wing-body lift at high Mach numbers.

The purpose of this article is to demonstrate experimentally that Eq. (2) is indeed valid. Experimental results of wing-body lift will be correlated using the lift interference factor $F$.

An experimental program was conducted using delta wing-body combinations of various aspect ratio and $d/b$ at subsonic Mach numbers (2 × 3 USAFA low-speed wind tunnel) and supersonic Mach numbers (1 × 1 USAFA Trisonic wind tunnel) of 1.44, 2.48, and 3.48. The $F$ value was determined using Eq. (1) and the experimental

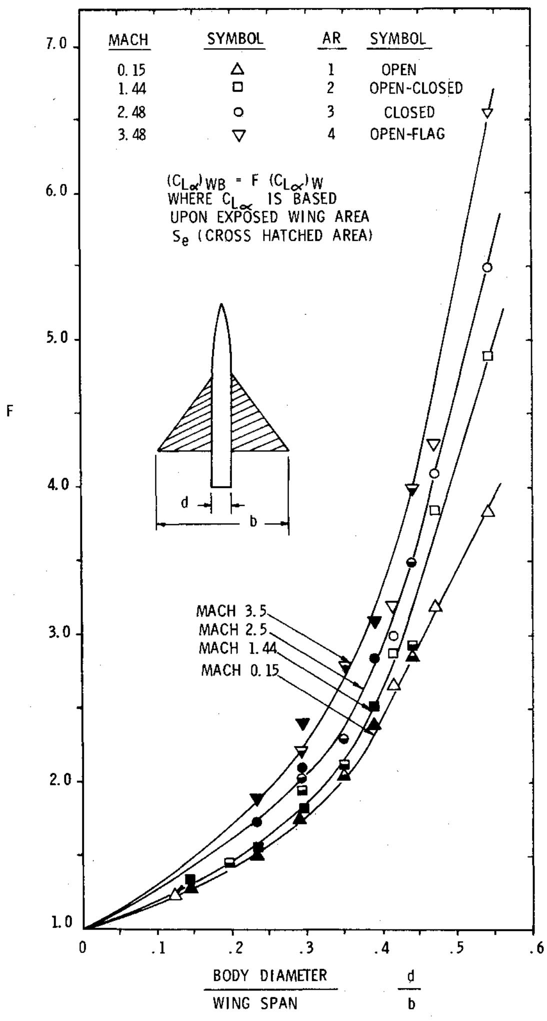


**Fig. 2 Wing-body lift interference factor.**

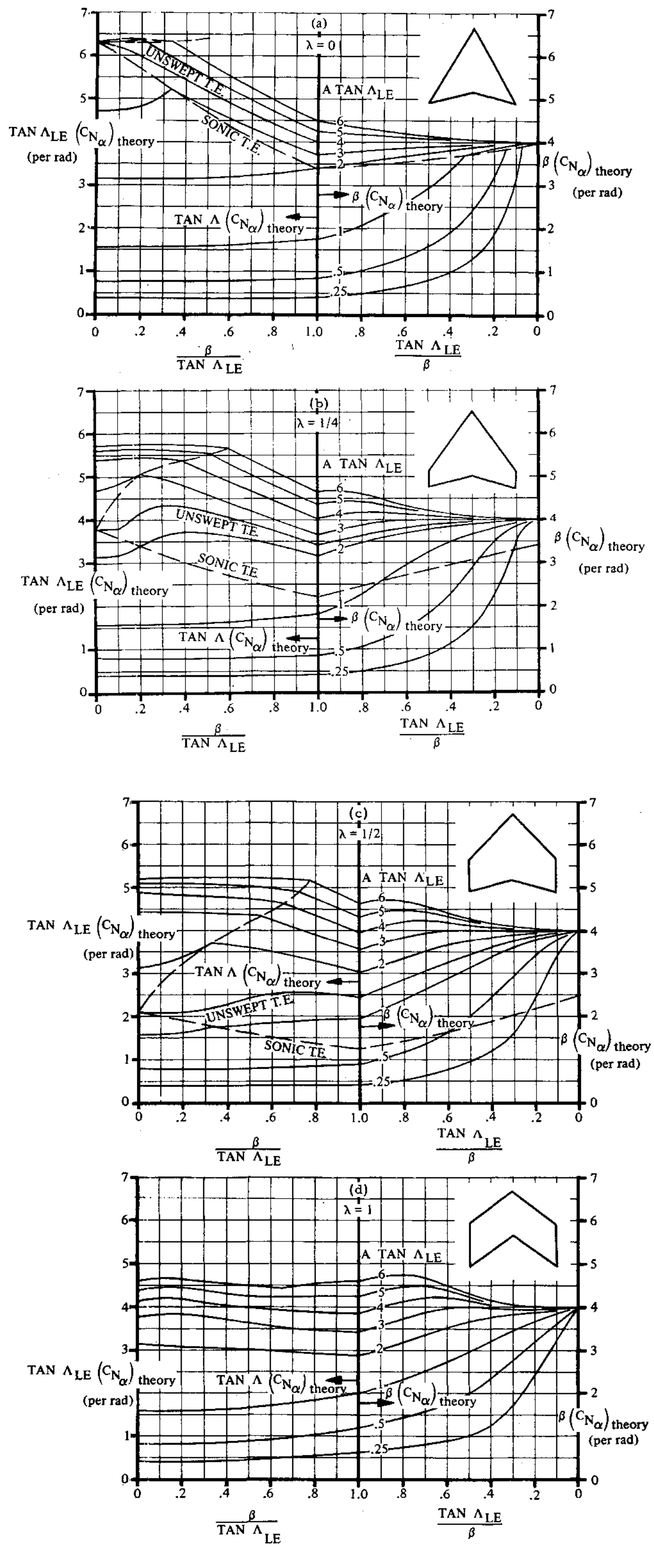


**Fig. 3 Theoretical supersonic wing alone lift curve slope.**

data of Hall[2] and the USAFA program mentioned above. The data of Hall[2] was used to show the first-order independence of $F$ on wing aspect ration, swéep, and taper ratio for Mach numbers up to 2.0. The data of the USAFA program was used to again show the independence of $F$ on wing aspect ratio and extend the examination of Mach number to 3.48. The results for $F$ are shown on Fig. 2 and demonstrate the dependence of $F$ on $d/b$ and Mach number. The $F$ values on Fig. 2 were checked using experimental data for a wide variety of wing planforms, Mach numbers and $d/b^1$ with agreement within ±15% in all cases. All of the wing-body configurations considered in this study were uncambered and untwisted and had the body extended sufficiently past the trailing edge of the wing so that the Mach lines from the wing root covered the afterbody (i.e., lift carryover was present).

Equation (1) and Fig. 2 can be used to rapidly determine the wing-body lift curve slope, $(C_L)_{WB}$. The methods, in three Mach regimes, are as follows:

*Subsonic:* Determine the wing $C_L$ using the expression[3]

$$(C_{L_\alpha})_W = \frac{2\pi A}{2 + [4 + A^2\beta^2(1 + \tan^2\Delta/\beta^2)]^{1/2}} \qquad (3)$$

where $A$ = aspect ratio, $\beta = (|1 - M^2|)^{1/2}$, $\Delta$ = sweep of the maximum thickness line. Then, determine $F$ from Fig. 2 for the $d/b$ and Mach number of interest. The wing-body $C_L$ based upon the exposed wing planform area $S_e$ is then given by Eq. (1).

*Transonic:* Determine the wing $C_L$ using the method suggested by Spreiter.[4] Then determine $F$ from Fig. 2 and use Eq. (1) for $(C_L)_{WB}$.

*Supersonic:* For $M \geq 1.4$, determine the wing $C_L$ using supersonic thin airfoil theory and finite wing theory such as is shown on the charts of Fig. 3 (Refs. 5-9). Then determine $F$ from Fig. 2 for the $d/b$ and Mach number of interest and calculate $(C_L)_{WB}$ using Eq. (1). This supersonic method is restricted to wing-body configurations where lift carryover is present.

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# Erratum

## "Simplification of the Wing-Body Interference Problem"

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EQUATION (3) in the preceding Engineering Note should have read as follows:

$$K_{B(W)} = [(1 - \frac{r^2}{s^2})^2 - \frac{2}{\pi}\{(1 + \frac{r^4}{s^4})[\frac{1}{2}\tan^{-1}\frac{1}{2}(\frac{s}{r} - \frac{r}{s}) + \frac{\pi}{4}] - \frac{r^2}{s^2}[(\frac{s}{r} - \frac{r}{s}) + 2\tan^{-1}\frac{r}{s}]\}]/(1 - \frac{r}{s})^2 \qquad (3)$$

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