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RESEARCH MEMORANDUM

SOME EFFECTS OF CONFIGURATION VARIABLES ON STORE

LOADS AT SUPERSONIC SPEEDS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

A large volume of data from several recent stores-research programs has been examined and analyzed and is sampled and illustrated in this paper. Comprehensive coverage of the important configuration variables, obtained by measurements of separate forces and moments on stores in a large number of positions, is shown to give an improved understanding of the factors affecting store loads.

INTRODUCTION

The many store and nacelle investigations which have been performed to date have demonstrated the large and important performance and load problems that can be incurred. Although these investigations have yielded valuable information for the specific configurations tested, they contributed little toward obtaining a basic understanding of this interference phenomenon, particularly at supersonic speeds. This is true because of the large number of configuration variables which affect store loads. It is the purpose of this paper to discuss and evaluate the effects of some configuration variables on store loads at supersonic speeds.

In view of the fact that a very wide range of store locations are in use or under consideration today, any treatment of the store problem must cover a large number of store positions. A recent wind-tunnel investigation, which will be the principal source of the data presented in this paper, accomplishes this and, in addition, treats a number of the configuration variables involved. Figure 1 shows the models and test "grid" for this investigation in the Langley 4- by 4-foot supersonic pressure tunnel at supersonic speeds. The model store was separately sting supported on a strain-gage balance which measured six components. The half-model of fuselage, wing, or wing-fuselage combination was mounted on a four-component balance in the tunnel boundary-layer bypass plate. The test grid through which the store was moved

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involved 8 fore-and-aft positions and 11 spanwise positions for a total of 88 store positions at each of several store vertical heights. Not all these test positions represent practical store positions, of course, but were included in order to make possible interference mapping of the entire area, with an eye toward an improved understanding of the source and distribution of the interferences. The angles of attack of only the wing and fuselage were varied up to 4°, the store remaining at 0° throughout. Several store shapes and sizes and several wing and fuselage configurations were investigated. (The delta wing is shown by dashed lines in fig. 1.) All the data from the Langley 4- by 4-foot supersonic pressure tunnel are for a store tested in the absence of a pylon.

With this equipment rather extensive work has been done; although much has been learned, there are many questions yet unanswered, particularly with regard to store loads. The data presented are the first results obtained with this technique and are useful in themselves as well as forming a guide for future work. A large volume of data has been examined and analyzed and will be sampled and illustrated in this paper. Store side force is used extensively because it has been shown to be generally the important load from the standpoint of pylon or support design. The other loads will be found in NACA reports on this work (for example, refs. 1 and 2).

SYMBOLS

C_Y	store side-force coefficient, $\frac{\text{Store side force}}{qF}$
C_N	store normal-force coefficient, $\frac{\text{Store normal force}}{qF}$
C_{Y_α}	slope of variation of store side-force coefficient with wing-fuselage angle of attack
q	free-stream dynamic pressure
F	maximum frontal area of store
D_s	maximum diameter of store
α	angle of attack of wing-fuselage center line
M	Mach number

RESULTS AND DISCUSSION

Figure 2 shows the store side force in the presence of the wing-fuselage combination at an angle of attack of 0° at $M = 1.6$. Force data from about 30 store positions were used to make this contour map. The lines show positions of the store midpoint for constant values of store side-force coefficient. For the store position shown, for example, the value of C_Y is 0.04. The shaded areas signify regions in which the store side force (for the store shown) is negative or toward the tip, whereas the unshaded areas signify regions in which the store side force is positive or toward the root. Note that the store side-force coefficient changes rapidly from -0.08 to 0.12 in a fairly short region of usable store positions and that the values change from peak maximum to zero or less in less than one wing-chord length. The value of C_Y of 0.12 corresponds to the side force developed by the isolated store at 4° of yaw. Note that the side-force values shown are for the store only; these data are for conditions with no pylon present except when specifically stated.

One of the first things to be considered in the problem of sorting out the important variables and understanding their influence is the matter of the relative contribution of the configuration components themselves. The results of some of the configuration breakdown tests are shown in figure 3. In this figure, the store side force and store normal force are plotted for an inboard, a midspan, and an outboard station in the presence of the wing and wing-fuselage combination. The squares in the upper plots are the same data included in the contour plot of figure 2. It can be seen from the C_Y curves for the inboard station that the contribution of both fuselage and wing to store side force in this position is important, mutual interference probably further confusing the effects. For the outboard station, the influence of the fuselage (as shown by the difference between the curves) has diminished but is still felt. In the case of normal force (lower half of fig. 3), the influence of the fuselage appears to be relatively unimportant for all store positions because the store lift in the presence of the wing-fuselage combination is almost exactly equal to the store lift in the presence of the wing alone. Data similar to these covering the other forces and moments are presented in references 1 and 2.

It might be pointed out in passing that the magnitudes of the variations in C_Y and C_N shown here are comparable with those measured for the other forces and moments (the store drag, yawing moment, and pitching moment). This condition applies to all the configurations but, since these effects are not fully understood, it is not known whether this result is general.

In order to determine the more important variables involved in the store-loads problem, it is necessary to eliminate some of the less important ones. One of these is vertical displacement between wing and store. Shown in figure 4 is a plot of store side force against store longitudinal position x for three spanwise stations: inboard, midspan, and tip. The data with the circle symbols is for a large space between wing and store and corresponds to the data previously shown in the contour plot (fig. 2). The effect of decreasing the vertical height is to increase the magnitude of the side-force variations, especially in the inboard position. Outboard, the effect of vertical height is smaller, and the character of the curves is essentially the same. The overall effect of vertical height is thus shown to be small within the range tested.

Another minor variable, the effect of store size on side force, is shown in figure 5. Although the character of the C_Y curves tends to be similar, some shifting is in evidence and very much larger values of maximum side-force coefficient were measured for the small store than for the large store. This phenomenon is explained by the fact that the small store can become more completely submerged in a region in which side force is generated (because of a pressure gradient or flow deviation or both) in one direction, either inward or outward. The large store, on the other hand, tends to extend through several such regions so that a lower peak value of side-force coefficient results.

It is significant to note that the slope of the curve of side-force coefficient with angle of attack C_{Y_α} (lower curves of fig. 5) is not appreciably affected by store size. This phenomenon is not fully understood, and it is not known whether this result applies outside the range of sizes tested in this investigation.

From the data shown in figure 2 and similar data for $\alpha = 2^\circ$ and 4°, the slope of side force with angle of attack has been obtained and is shown in contour-map form in figure 6. It can be seen that the slopes vary greatly with store location and that for some store locations the slopes are so great that very high loads may be encountered at high angles of attack for these locations. The store side-force coefficient C_{Y_α} increases toward the wing tip as would be expected from the fact that the sidewash increases as the tip is approached and as the lift is increased. Large changes in C_{Y_α} can also be experienced in moving the store from the leading edge of the wing to the trailing edge of the wing near the midspan. These data were taken by changing the wing-fuselage angle of attack, as mentioned earlier. The fact that the store remained at $\alpha = 0^\circ$ affects the store normal force but not to any appreciable extent the store side force. The effect of the small change in vertical displacement between wing and store which occurs when the wing-fuselage angle of attack is changed is, as has been shown previously, small and unimportant compared with the effects now being considered.

This C_Y contour map was prepared from data limited to an angle of attack of 4°. For many conditions, angles considerably higher are of interest and may, as suggested by the data shown here, be a design or limiting condition for store loads. Some data from an investigation in the Langley 9- by 12-inch blowdown tunnel involving similar tests of two store positions up to higher angles of attack provide some information on this point. Figure 7 shows the variation of C_Y with α for a store at midspan position up to an angle of attack of 12°. Shown for comparison are curves taken from the mapped data of figures 2 and 6 for a comparable (midspan) store position and two others - one inboard and the other near the wing tip. It will be noted from the configuration sketches labeling the curves that configuration differences exist. The configuration on which the high angle-of-attack data were obtained involves a smaller store, a shorter fuselage nose, and a lower wing taper. The effects of these differences are measurable but, as was shown previously for the case of store size and the effect of the fuselage, are not important for the comparisons made here. The side-force data chosen from some of the mapped data shown previously for a comparable store location agree well with the data from the blowdown tunnel. This agreement lends credence to the extrapolation of the mapped data to reasonably high angles of attack. The curves shown for the inboard and tip, however, are greatly different and show the important effect of store position on the maximum side-force loads which can be encountered. In the absence of adequate mapped data at higher angles of attack, it appears that the data available for a limited number of store positions from the Langley 9- by 12-inch blowdown tunnel might be used as a guide for judicious extrapolation of the mapped data as shown in figure 6.

Turning now to the effects of another variable, the wing plan form, figure 8 shows a contour map of C_{Y_α} for the delta wing for comparison with the same data for the swept wing (fig. 6). The highest values are obtained at the tip, as in the case of the swept wing, but the chordwise variation of C_{Y_α} is essentially zero in the case of the delta wing, in contrast with the considerable variation shown for the swept wing.

These data, like the swept-wing data shown previously, are limited to an angle of attack of 4°. Again, these data can be correlated with the blowdown tunnel data on a similar delta-wing configuration. Figure 9 shows the variation of C_Y with α for this configuration (shown shaded) up to $\alpha = 12^{\circ}$. Shown for comparison is a curve for the same store position from the mapped data for the delta-wing configuration tested in the Langley 4- by 4-foot supersonic pressure tunnel. These data agree well as to general slope and values of side force indicated up to 12°. Also shown in figure 9 are curves from the mapped data for a store at an inboard position and at a tip position. Again, as in the case of the swept wing, the effect of store position is shown to be important. Extrapolation of the mapped data to higher angles of attack, using the data from the Langley 9- by 12-inch blowdown tunnel as a guide, also appears to be feasible in the case of the delta wing.

The foregoing data involve only the load on the store and do not consider either the load on the pylon itself or the effect of the pylon on the store loads. Unfortunately, little or no data exist at present on pylon loads. Some information is available, however, on the effect of a pylon on store loads. Figure 10 shows the data from the Langley 9- by 12-inch blowdown tunnel for the variation of store side force with angle of attack, the space between store and wing being open and this space being filled with an unswept support pylon (as shown in the sketch in fig. 10). The pylon is attached to the wing but does not touch the store. It can be seen that the large store side force which is produced as the angle of attack is increased is more than doubled when the pylon is present. Since these large loads added to the unknown but undoubtedly large load on the pylon are somewhat terrifying, it is of interest to speculate a bit as to whether these limited data are showing a general situation.

Since the store in this position is experiencing a high side load, it is probable that the pylon is also in a region of high side load. The pylon-store combination can be considered to be comparable to a wing-tip-store configuration under lifting conditions. It has been shown that at angle of attack a tip store experiences an interference lift because of the presence of the wing which is dependent on the angle of attack and on the wing plan form and may be influenced by other factors. Location of the pylon in a region of lower side loads could be expected to reduce the loads induced on the store and on the pylon. A change in pylon plan form could also be expected to affect these loads.

From an examination of this and other limited data by using the above assumptions, it is believed that the increment in side force due to the pylon shown in figure 10 is an extreme case. Further research is needed on the effect of pylons and on pylon loads themselves.

All the previous figures have pertained to store or nacelle configurations having no tail fins. The effect of tail fins on a large store is shown in figure 11. In figure 11, the side force C_Y and the slope of side force with angle of attack C_{Y_α} are plotted against store chordwise position x for three spanwise positions. The C_Y curves for stores with and without fins undulate in similar fashion, but the peak value (both positive and negative) of C_Y attained is larger for the finned store in all cases. The actual value of C_Y for any one store position may be either higher or lower. These effects are the result of the presence of the fins in regions of strong crossflow or pressure gradients.

Figure 11 appears to indicate that the regions of inward and outward force which exist are strong and relatively sharply defined. It is apparent that the effect of adding fins to a store can be known only if specific test data are available or if very detailed information on the flow field is available.

The data presented herein are consequently being analyzed with the aim of providing an improved understanding of the flow field. A useful picture of the flow field has been formulated in the case of drag, where simple buoyancy concepts were found to explain the drag interference between components (ref. 1). The buoyancy concept was found inadequate in dealing with other forces, however, because flow angularity is important, if not predominant, in the production of these forces. Other approaches are being attempted, based upon the large amount of mapped force data available.

CONCLUDING REMARKS

In recent research, sufficient coverage of important variables has been included to give an improved understanding of the factors affecting store loads. For a given wing plan form, store position and configuration angle of attack have been shown to be the two most important parameters in the evaluation of store side force, and these two items are so intertwined as to require careful consideration of both. The effects of other variables such as store size, vertical displacement, and fins have been illustrated.

The effect of a supporting pylon has been shown to be large and important, although the factors governing the effects of pylons are not fully understood and more work is needed on both the effect of pylons and on the pylon loads themselves.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 21, 1955.

REFERENCES

1. Smith, Norman F., and Carlson, Harry W.: The Origin and Distribution of Supersonic Store Interference From Measurement of Individual Forces on Several Wing-Fuselage-Store Configurations. I. - Swept-Wing Heavy-Bomber Configuration With Large Store (Nacelle). Lift and Drag; Mach Number, 1.61. NACA RM L55A13a, 1955.

2. Smith, Norman F., and Carlson, Harry W.: The Origin and Distribution of Supersonic Store Interference From Measurement of Individual Forces on Several Wing-Fuselage-Store Configurations. II. - Swept-Wing Heavy-Bomber Configuration With Large Store (Nacelle). Lateral Forces and Pitching Moments; Mach Number, 1.61. NACA RM L55E26a, 1955.

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MODELS AND TEST GRID

EACH + INDICATES A STORE MIDPOINT LOCATION

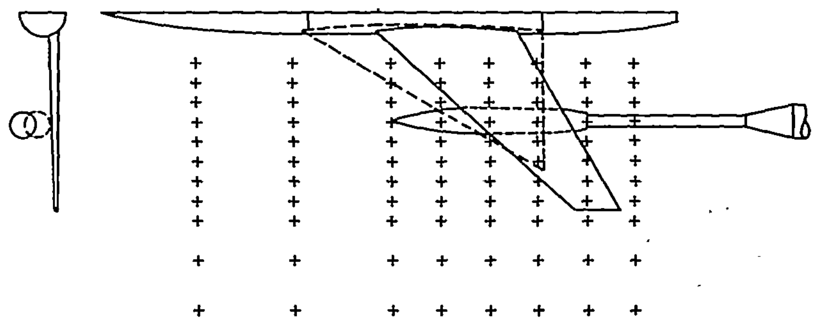

Figure 1

STORE SIDE-FORCE COEFFICIENT

SWEPT WING; M=1.6; α=0°

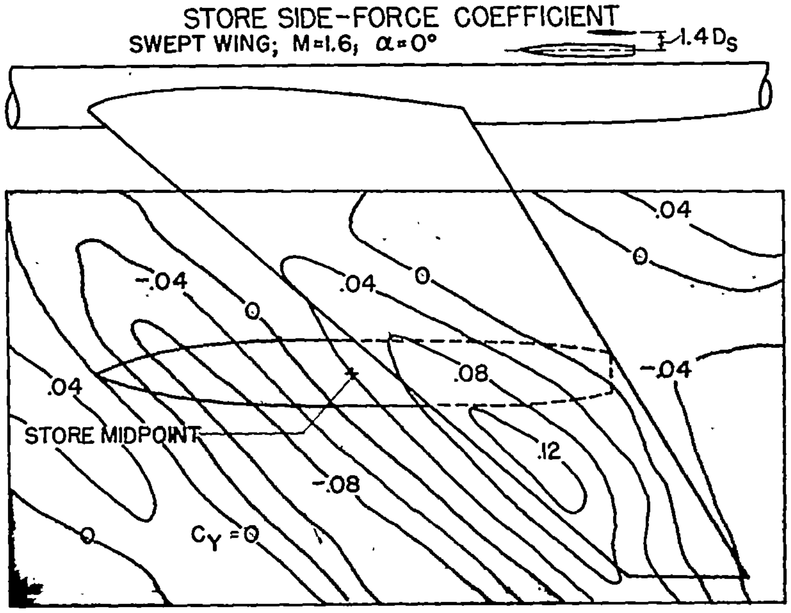

Figure 2

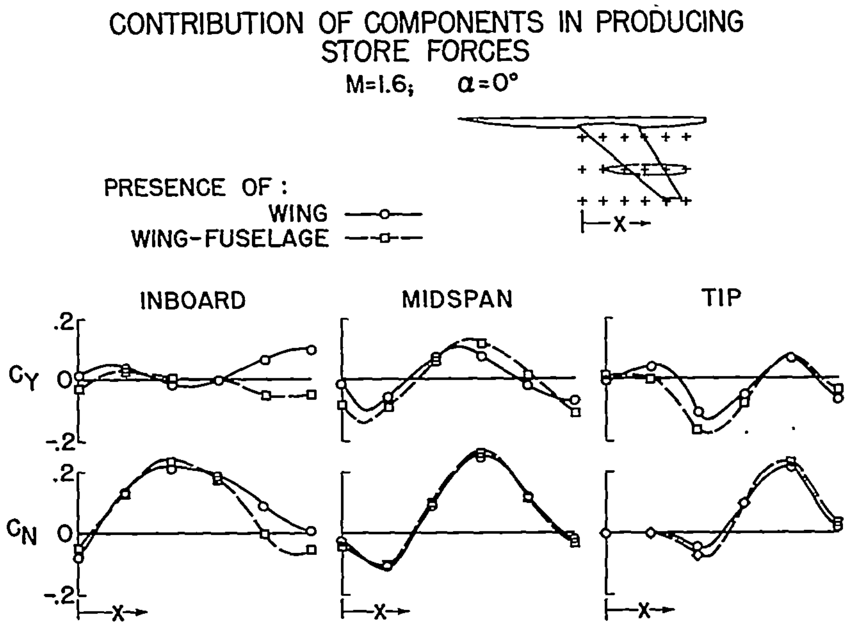

Figure 3

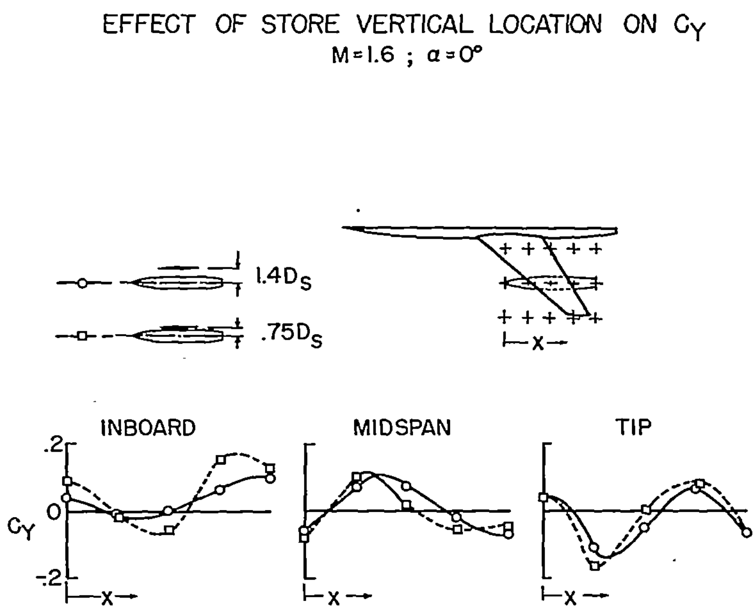

Figure 4

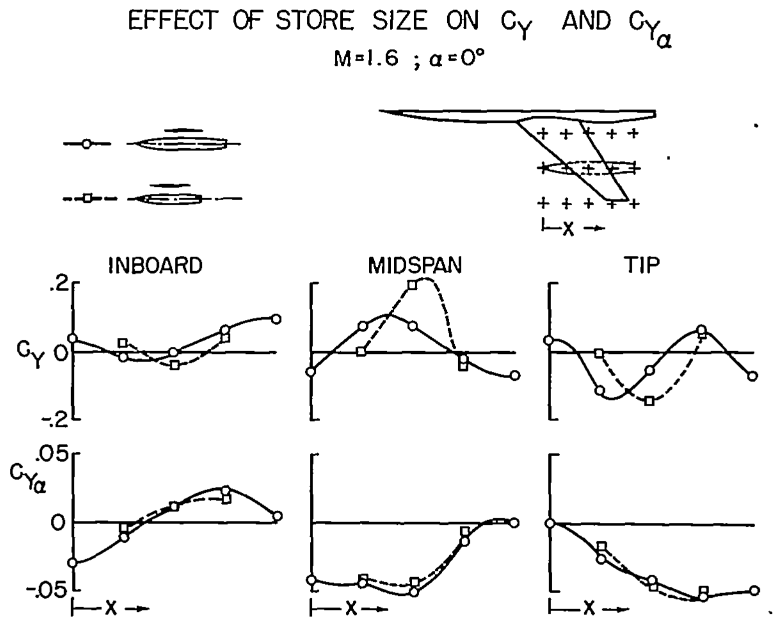

Figure 5

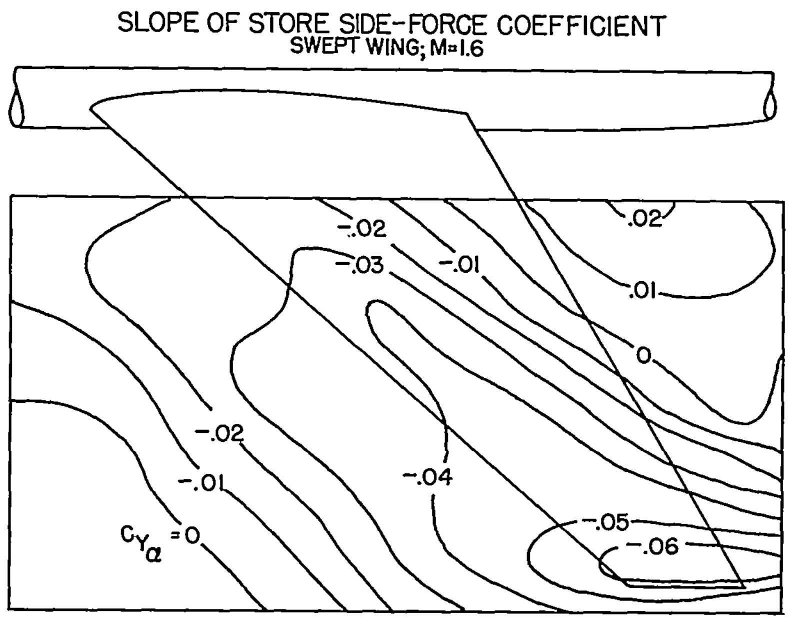

Figure 6

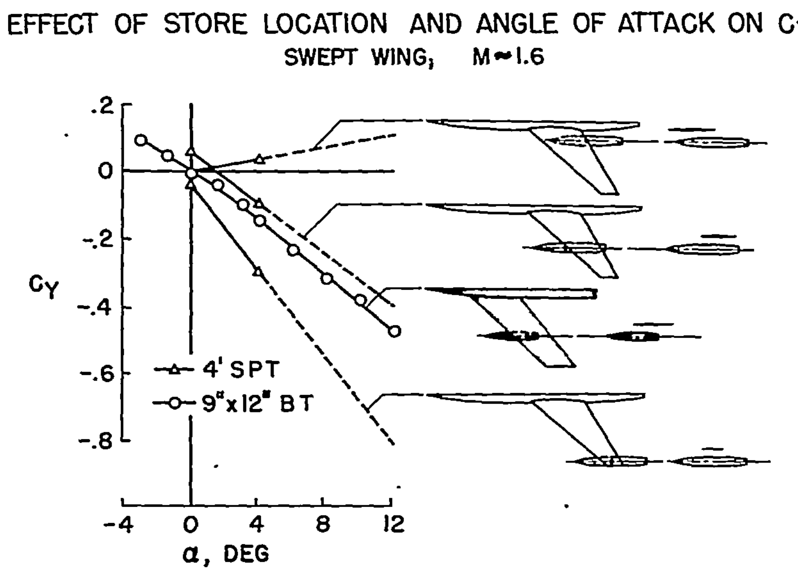

Figure 7

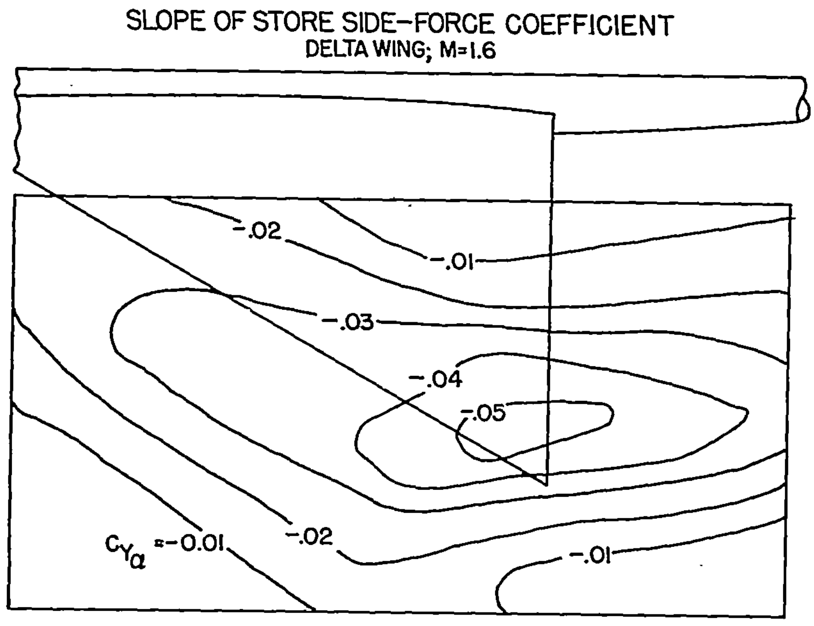

Figure 8

HADC 55-3094 L

EFFECT OF STORE LOCATION AND ANGLE OF ATTACK ON C_Y

DELTA WING; $M \approx 1.6$

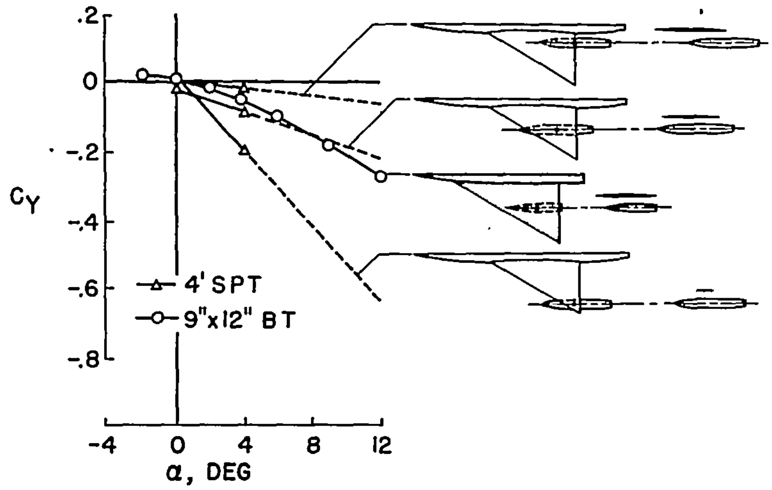

Figure 9

EFFECT OF PYLONS ON C_Y

9" x 12" BT; $M \approx 1.6$

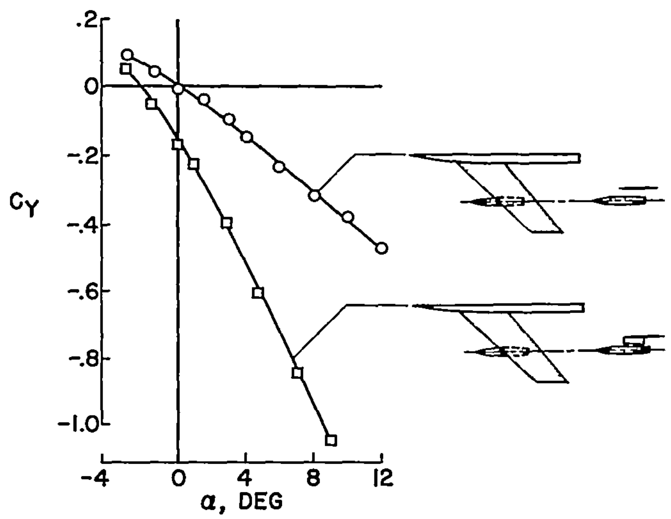

Figure 10

EFFECT OF STORE FINS ON C_Y AND C_{Y_α}

M = 1.6

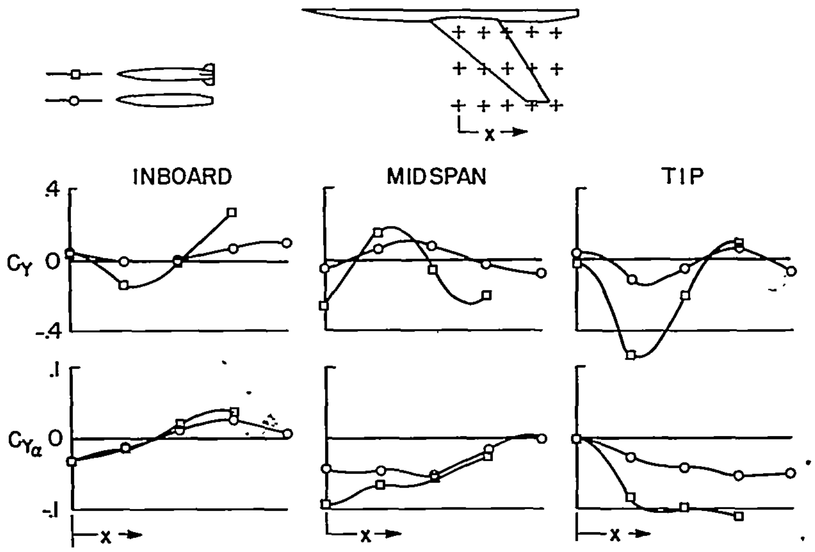

Figure 11