3. EFFECTS OF EXTERNAL STORES

Methods are presented in this section for estimating the effects of externally mounted stores on aircraft stability characteristics. The methods predict the incremental effects due to the installed stores on the aircraft characteristics, not the isolated-store characteristics or the effect of the aircraft on the stores. Section 3 is subdivided as follows:

3.1 Effect of External Stores on Aircraft Lift
3.2 Effect of External Stores on Aircraft Drag
3.3 Effect of External Stores on Aircraft Neutral Point
3.4 Effect of External Stores on Aircraft Side Force
3.5 Effect of External Stores on Aircraft Yawing Moment
3.6 Effect of External Stores on Aircraft Rolling Moment

No suitable general methods have been developed for predicting the effect of stores on aircraft rolling moment, and therefore no Datcom methods have been provided in Section 3.6.

Methods for predicting effects of external stores can be grouped into theoretical, experimental, and empirical, or combinations thereof. Numerous attempts have been made to develop analytical methods for store effects. Reference 1 discusses many of the approaches and provides an extensive bibliography of theoretical methods. The methods tend to be complex and often require elaborate computer programs and extensive computations. Theoretical methods are basically in an early stage of development. They often require simplifications and assumptions which do not lend their application to be generalized over a wide range of loading configurations. Experimental methods include those which utilize increments from flight, wind-tunnel, ballistics or other test data. Access to data and time required for its interpretation are the primary limitations of experimental methods. Reference 1 discusses experimental approaches to computing store effects and provides a bibliography of methods and sources of data. Empirical methods have been developed and documented (References 2 and 3) which seem to provide the best general approach for estimating external-store effects. Empirical methods make use of test-data correlation and theoretical concepts to arrive at prediction equations. The Datcom methods are empirical in nature.

The Datcom methods are taken from Reference 3. Reference 3 is a very comprehensive effort that collected, reviewed, and correlated methods and existing test data to develop generalized prediction equations. Reference 3 also documents wind-tunnel tests which were designed specifically to provide a data base for empirical equation development. A very extensive list of references is also provided.

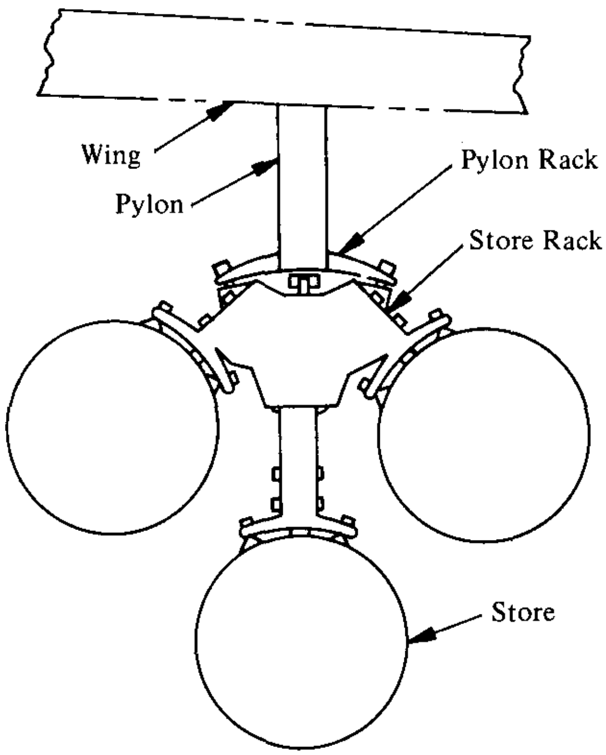
The Datcom methods in general require that the user provide only aircraft, store, and installation hardware geometric information in order to compute the aerodynamic effects of the store-aircraft combination. In some instances, the user is required to provide clean-aircraft data and isolated-store data. Because the methods are empirical in nature, the physical significance of some terms is not explained. The user should consult References 2 and 3 for additional insight into the method development.

The methods are applicable for wing- and fuselage-mounted conventional stores which are symmetrically or asymmetrically loaded, and are mounted on conventional-type subsonic or supersonic aircraft. This comprises nearly all conventional store configurations encountered. In most instances the methods also account for multiple carriage, mixed and multiple loading cases, and interference effects involving adjacent stores and the fuselage. The methods have not been substantiated for tip- or tangent-mounted wing stores. Specific limitations and assumptions involving configuration, flight envelope, and data base for method development are discussed in each of the individual sections.

Relatively little substantiation data is provided herein since the method substantiation is well documented in References 2 and 3. Expected accuracies of the methods are discussed in each section.

NOTATION

For the purposes of this section, a store installation refers to all armament-associated hardware including stores at one armament station and external to the clean aircraft. Installation hardware may include pylon, pylon rack, store rack, special adapters and launchers, sway braces, and stores. Typical installation hardware is illustrated in Sketch (a).



SKETCH (a)

Stores are carried in either a single or multiple carriage mode, and are either pylon- or tangent-mounted. In a single carriage mode, the store is mounted directly on the pylon rack or fuselage. The two multiple carriage modes considered by the Datcom methods are:

TER: Stores are mounted on a triple-ejector rack attached to the pylon rack or fuselage. This rack carries a maximum of three stores.

MER: Stores are mounted on a multiple-ejector rack attached to the pylon rack or fuselage. This rack carries a maximum of six stores.

A general notation list is included in this section for all sections included in Section 3. Since this notation list is quite extensive and the major portion of it includes notation peculiar to the Datcom Methods presented in Section 3, it is not integrated into the notation list presented as Section 2.1.

SYMBOL	DEFINITION
A_W	wing aspect ratio, based on total trapezoidal planform
A_1	longitudinal-location factor (side force)
A_2	store-size correlation factor (side force)
a_1, a_2, a_3	store-diameter correlation factors (drag)
B	basic-store-installation equivalent-parasite-drag area (ft^2) computed at $M = 0.9$
B_{ASC}	aft-store-cluster contribution (yawing moment)
B_e	protrusion of store fins beyond store body
B_{FSC}	forward-store-cluster contribution (yawing moment)
B_N	basic-store contribution term (side force)
B_P	pylon contribution (side force and yawing moment)
B_R	rack contribution (side force)
B_{SB}	store-body contribution (yawing moment)
B_{SF}	store-fin contribution (yawing moment)
B_X	pylon-longitudinal-location contribution (side force)
B_{xx}	empty-pylon factor (drag)
B_Y	pylon spanwise-location contribution (side force)

SYMBOL	DEFINITION
b_c	maximum vertical store-cluster span (in.), excluding protruding fins
b_e	exposed wing span
b_F	store-fin span (in.)
b_H	span of the aircraft tail
b_W	aircraft wing span
b_1, b_2, b_3	store-row Mach-correlation factors (drag)
C_{D_π}	isolated-store drag coefficient at zero lift
C_{D_0}	clean-aircraft zero-lift drag coefficient
C'_{D_0}	clean-aircraft drag-rise factor
C_L	clean-aircraft lift coefficient
$\left(C_{L_\alpha}\right)_{SB}$	store-body lift-curve slope
$\left(C_{L_\alpha}\right)_{SF}$	store-fin lift-curve slope
$C_{L_{\alpha_{S_{ij}}}}$	free-stream lift-curve slope of store j on installation i
$\left(C_{L_\alpha}\right)_{WB}$	wing-body, clean-aircraft lift-curve slope
C_{n_β}	rate of change of yawing-moment coefficient with sideslip angle
C_{Y_β}	rate of change of side-force coefficient with sideslip angle
ΔC_D	drag-coefficient increment due to external stores
ΔC_L	lift-coefficient increment due to external stores
$\Delta C_{L_{FS}}$	lift-coefficient increment due to fuselage-mounted stores

SYMBOL	DEFINITION
$\Delta C_{L_{WS}}$	lift-coefficient increment due to wing-mounted stores
ΔC_{n_β}	incremental change in C_{n_β}
ΔC_{Y_β}	incremental change in C_{Y_β}
c, c_i, c_{ij}	local wing chord at store or pylon station (in.)
$\bar{c}$	wing mean aerodynamic chord
$c_{p_{low}}$	pylon-bottom chord length (in.)
$c_{p_{top}}$	pylon-top chord length (in.) at wing-pylon juncture
c_r	wing root chord (in.)
D_B	zero-lift equivalent-parasite-drag area (ft^2) due to the basic store installation
D_{EM}	empty-MER equivalent-parasite-drag area (ft^2)
D_{ET}	empty-TER equivalent-parasite-drag area (ft^2)
D_{FLM}	fully loaded MER equivalent-parasite-drag area (ft^2)
D_{FLT}	fully loaded TER equivalent-parasite-drag area (ft^2)
D_{FR}	fuselage-rack equivalent-parasite-drag area (ft^2)
D_I	pylon-store-aircraft-interference equivalent-parasite-drag area (ft^2) at $M = 0.9$
D_{I_f}	equivalent-parasite-drag area (ft^2) at zero lift due to the mutual interference of store installation and adjacent fuselage
D_{ILP}	installed-loaded-pylon equivalent-parasite-drag area (ft^2)
D_{IM}	store-MER-aircraft-interference equivalent-parasite-drag area (ft^2)
D_{IMR}	installed-MER equivalent-parasite-drag area (ft^2)
D_{IS}	isolated-store equivalent-parasite-drag area (ft^2) at $M = 0.90$

SYMBOL	DEFINITION
D_{I_S}	zero-lift equivalent-parasite-drag area (ft^2) due to the mutual inteference of adjacent store installations (per pair of adjacent installations)
D_{IT}	store-TER-aircraft-interference equivalent-parasite-drag area (ft^2)
D_{ITR}	installed-TER equivalent-parasite-drag area (ft^2)
D_i	equivalent-parasite-drag area (ft^2) due to lift
D_{LPF}	equivalent-parasite-drag area (ft^2) due to the empty pylon on the fuselage
D_{MRF}	zero-lift equivalent-parasite-drag area (ft^2) due to a MER on the fuselage
D_{MSB}	MER sway-brace equivalent-parasite-drag area (ft^2)
D_{PR}	pylon-rack equivalent-parasite-drag area (ft^2)
D_{TSB}	TER sway-brace equivalent-parasite-drag area (ft^2)
D_X	store-to-aircraft-interference equivalent-parasite-drag area (ft^2)
d_c	minimum clearance between adjacent stores (in.)
d_S	maximum store diameter (in.)
d_{w_A}	maximum width (in.) of the aft-store installation
d_{w_L}	maximum width (in.) of the lead- (most forward) store installation
d_w	defined width (in.) of the store installation not including protruding fins
d_{wing}	distance (in.) from fuselage lower surface at store midpoint to average wing lower surface at wing root
E_u	pylon-height interference factor (drag)
$(FS)_{LE}$	fuselage station (in.) of the nose of the most forward store on the installation or the fuselage station of the leading edge of the pylon for the empty-pylon case
$(FS)_{ref}$	fuselage station (in.) of the moment reference point

SYMBOL	DEFINITION
F_R	ratio of store-fin area (projected onto a horizontal plane) to store-body planform area
$F_1(M)$	MER Mach-effect factor for fuselage-tangent-mounted or fuselage-pylon-mounted installations (pitching moment)
$F_1\left(\bar{x}_{SN_{ij}}\right)$	store longitudinal-placement parameter for TER or MER carriage (pitching moment)
$F_1\left(\bar{x}_{SN_{ij}}, F_R\right)$	store longitudinal-placement and fin-area-ratio parameter for wing pylon-mounted stores (pitching moment)
$F_2(M)$	MER Mach and store-station factor for fuselage tangent-mounted installations (pitching moment)
$F_2(M,j)$	Mach and store-station effect parameter (pitching moment)
$F_{21}\left(\bar{x}_{SN_{ij}}\right)$	store longitudinal-placement factor for wing-pylon-mounted single stores or MER carriage (pitching moment)
$F_{22}\left(\bar{z}_{ij}\right)$	store vertical-placement factor for wing pylon-mounted single stores or MER carriage (pitching moment)
$F_{23}\left(F_R\right)$	store-fin area-ratio factor for wing pylon-mounted single stores (pitching moment)
$F_{23}(M)$	Mach-effect factor for MER carriage (pitching moment)
$F_3(M,j)$	MER Mach and store-station-effect parameter (pitching moment)
h_f	overall fuselage height (in.)
h_p	average pylon height (in.)
I_{S_j}	MER installation neutral-point correlation factor (pitching moment)
K_{AWA}	longitudinal-location factor for multiple rack (lift)
K_{CJK}	pylon Mach-number correlation parameter (drag)
K_{D_1}	store frontal-area factor (drag)
K_{D_2}	wing-sweep-and-location factor (drag)

SYMBOL	DEFINITION
K_{D_3}	tandem-spacing factor (drag)
K_{D_4}	lateral-spacing factor (drag)
K_{D_5}	store-rows factor (drag)
K_{D_6}	stores-per-row factor (drag)
K_{D_7}	store longitudinal-location factor (drag)
K_F	fin constant (side force)
K_f	fuselage proximity-effect parameter (lift)
K_H	pylon-height factor (lift)
K_{HF}	lateral store-to-fuselage clearance parameter (lift)
K_{IF}	installation factor (drag)
K_M	Mach-effect factor (side force)
K_{NB}	nose-shape parameter (pitching moment)
K_{NI}	planform and store-location factor
K_p	pylon-height-effect parameter (lift)
K_{PC}	pylon constant (side force)
K_{PD}	pylon-depth factor (drag)
K_{SD}	store-depth factor (drag)
K_{S_M}	Mach-effect factor for K_{D_1} (drag)
K_{SPAN}	store-installation lateral-placement parameter (lift)
$K_{S_{ij}}$	loading-configuration factor (pitching moment)

SYMBOL	DEFINITION
K_{VF}	fuselage vertical clearance parameter (lift)
K_W	store-installation-width factor (lift)
K_{WING}	wing-location parameter (lift)
K_X	store-placement factor (lift)
K_{xx}	empty-pylon correlation ratio (drag)
K_y	store-installation-depth factor (side force)
K_{y_i}	horizontal-tail span-location factor (pitching moment)
K_{z_i}	horizontal-tail vertical-location factor (pitching moment)
K_Λ	wing-sweep-effect parameter (lift)
K_1	span-location factor (pitching moment)
K_2	longitudinal-correction factor (pitching moment)
K_3	Mach-number-correction factor (pitching moment)
L_{LE}	incremental-lift effect of the longitudinal location of multiple-mounted stores along the local wing chord (lift)
L_R	incremental-lift effect due to carriage-rack installation (lift)
$L_{\alpha_{FS}}$	fuselage-stores incremental-lift effect due to angle of attack (lift)
$L_{\alpha_{WS}}$	wing-stores incremental-lift effect due to aircraft angle of attack (lift)
ℓ_{AFT}	length (in.) of aft-store installation (drag)
ℓ_{ASC}	aft-store-cluster moment arm (in.) (yawing moment)
ℓ_{EM}	length of empty MER (in.)
ℓ_{ET}	length of empty TER (in.)

SYMBOL	DEFINITION
ℓ_m	moment arm (in.) from the moment reference point to the effective point of application of the side-force increment due to external stores (yawing moment)
ℓ_{m_1}	value of ℓ_m for the first of a pair of adjacent store installations (in.) (yawing moment)
ℓ_{m_2}	value of ℓ_m for the second of a pair of adjacent store installations (in.) (yawing moment)
ℓ_n	longitudinal distance (in.) from the store nose of the forward cluster to the store nose of the aft cluster
ℓ_P	pylon moment arm (in.) (yawing moment)
ℓ_S	store-body length (in.)
ℓ_{SB}	store-body moment arm (in.) (yawing moment)
ℓ_{SF}	longitudinal distance (in.) from the store nose to the intersection of the store-fin quarter chord and the store-fin 50% semispan
ℓ_{SP}	maximum store/pylon installation length (in.)
ℓ_x	longitudinal distance (in.) from $(FS)_{LE}$ to the point of side-force application, positive aft
ℓ_1	length of store installation 1.
ℓ_2	length of store installation 2.
M	Mach number
MER	multiple-ejector rack
M_{I_I}	MER adjacent-store separation factor (drag)
M_{I_S}	store-MER-aircraft-interference Mach-correlation factor (drag)
N_{A_i}	total number of asymmetrical external-store installations
N_F	number of store installations adjacent to the fuselage

SYMBOL	DEFINITION
N_I	total number of store installations on the aircraft
N_{I_f}	total number of fuselage-mounted store installations on the aircraft
N_P	total number of pairs of adjacent store installations carried
N_{S_M}	total number of stores attached to the MER
N_{S_T}	total number of stores attached to the TER
N_{S_i}	total number of pairs of symmetrical external-store installations
n_P	number of pylons
n_r	number of stores per row (fuselage mounting)
n_{s_i}	total number of store stations on installation i
P	clean-aircraft drag-rise factor
R_{A_M}	MER aft-longitudinal-placement term (drag)
R_{A_T}	TER aft-longitudinal-placement term (drag)
R_D	basic-stores-correlation factor (side force)
R_{F_M}	MER forward-longitudinal-placement factor (drag)
R_{F_T}	TER forward-longitudinal-placement factor (drag)
R_i	normalized incremental drag due to lift
R_{LC}	aft-store-cluster lateral-clearance factor (yawing moment)
R_{NEG}	adjacent-store interference factor (side force)
R_U	pylon-underside-roughness factor
S_B	maximum fuselage frontal area (ft^2)

SYMBOL	DEFINITION
S_F	store-fin area (in.^{2}) projected onto horizontal plane
S_P	maximum pylon cross-sectional (frontal) area (in.^{2})
S_p	store-body planform area (in.^{2})
S_W	aircraft wing reference area (ft^2)
S_{W_a}	1) affected wing area (in.^{2}) of both wings (for wing-mounted installations); 2) pseudo store installation planform area (in.^{2}) for both installations (for fuselage-mounted installations)
$S_{W_{a_B}}$	pseudo-store-body vertically projected area (in.^{2}) on one wing
$S_{W_{a_F}}$	vertically projected area (in.^{2}) on the wing of the unobstructed, exposed-fin areas of the stores at the given store station for one installation
S_π	store maximum cross-sectional area (ft^2)
T_A	transonic-supersonic correlation factor (drag)
TER	triple-ejector rack
T_F	tandem-stores factor (drag)
T_{I_I}	TER adjacent-store separation factor (drag)
T_{I_S}	store-TER-aircraft-interference Mach-correlation factor (drag)
T_N	distance from the nose of the aft-store installation to the tail of the lead-store installation (in.)
$t_{p_{max}}$	maximum pylon thickness (in.)
$U_{\bar{y}}$	lateral interference factor (drag)
$V_{\bar{x}}$	longitudinal interference factor (drag)
X_A	absolute longitudinal distance (in.) from the trailing edge of one store installation to the trailing edge of the adjacent store installation

SYMBOL	DEFINITION
X_F	absolute longitudinal distance (in.) from the nose of one store installation to the nose of the adjacent installation
X_{OL}	ratio of longitudinal spacing between tandem stores to the store length
x_{AFT}	longitudinal distance from the local wing trailing edge to the trailing edge of the store installation (in.) (or pylon trailing edge for the empty pylon case), positive in the aft direction
$x_{a.c.}$	wing-body aerodynamic-center location of the clean aircraft measured from the leading edge of the mean aerodynamic chord (in.)
x_{FWD}	longitudinal distance from the wing leading edge at the store location to the store/pylon nose (in.), positive for store nose aft of the wing leading edge
x_{ML_i}	distance (in.) from the local wing leading edge to the point midway between the pylon mounting lugs on installation i, positive in the aft direction
$x_{S_{ij}}$	distance (in.) from the leading edge of the mean aerodynamic chord $\bar{c}$, to the point midway between the mounting lugs of the installed store for store j on installation i, positive in the aft direction
$x_{SN_{ij}}$	distance (in.) from the local wing leading edge to nose of store j on installation i, positive in the aft direction
x_r	ratio of the distance between the aircraft nose and the store nose of the most forward store to the aircraft fuselage length
$\Delta x_{n.p.}$	total aircraft neutral-point shift due to external-store installations, positive for aft shift (in.)
$\Delta x_{n.p._1}$	shift in neutral point due to lift transfer from the stores to the clean aircraft, positive for aft shift (in.)
$\Delta x_{n.p._2}$	shift in neutral point due to the interference effects on the wing flow field, positive for aft shift (in.)
$\Delta x_{n.p._3}$	shift in neutral point due to the change in tail effectiveness caused by external stores, positive for aft shift (in.)
$\Delta x'_{n.p._2}$	neutral-point basic-interference-effect term
$\Delta x'_{n.p._3}$	neutral-point horizontal-tail term

SYMBOL	DEFINITION
Y_{A_β}	side-force contribution (ft^2/deg) per degree sideslip due to interference effects from a pair of adjacent external-store installations
Y_{B_β}	basic side-force contribution (ft^2/deg) per degree sideslip due to a symmetrical pair of external-store installations
$\left(Y_{B_\beta}\right)_1$	value of Y_{B_β} for the first of a pair of adjacent installations
$\left(Y_{B_\beta}\right)_2$	value of Y_{B_β} for the second of a pair of adjacent installations
Y_{OD}	ratio of minimum lateral distance between stores (excluding fins) to maximum store diameter
Y_S	minimum lateral clearance (in.) between adjacent store installations
y_i	spanwise distance from the fuselage centerline to the location of installation i
y_i'	spanwise distance from the outboard edge of the fuselage to the location of installation i
y_{ij}	spanwise distance from fuselage centerline to centerline of store j on installation i
$\bar{y}$	fraction of wing semispan location of store station measured from aircraft centerline
ΔY	minimum clearance (in.) between store installation and the fuselage
z	maximum depth of the store installation (in.) measured from the bottom surface of the wing
$\bar{z}$	ratio of vertical distance between average wing lower surface and store centerline to local wing chord
z_e	vertically projected length (in.) of the store installation on the aircraft wing
z_{ij}	distance (in.) from the wing lower surface to the centerline of store j on installation i, positive in the downward direction
z_{T_i}	vertical distance from wing lower surface at installation i to mid-line of the horizontal tail

SYMBOL	DEFINITION
z_w	distance from the top of the fuselage to the midpoint of the wing intersection with the fuselage (in.)
α	aircraft angle of attack
δ	equivalent-parasite-drag area (ft^2)
δ_{s_i}	configuration-related interference parameter (pitching moment)
θ_n	store nose-cone half-angle (deg)

REFERENCES

1. Culley, R. J.: Store Interference Force Prediction Survey. Masters Thesis, California State University, Long Beach, 1975. (U)

2. Gallagher, R. D., and Jimenez, G.: Technique Development for Predicting External Store Aerodynamic Effects on Aircraft Performance. AFFDL-TR-72-24, 1972. (C) Title Unclassified

3. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

3.1 EFFECT OF EXTERNAL STORES ON AIRCRAFT LIFT

Methods are presented in this section for estimating the change in aircraft lift due to external-store installations. The methods predict an incremental change in lift coefficient, based on wing reference area, which can be added to the clean-aircraft lift coefficient to obtain the aircraft-with-stores lift coefficient. These methods are taken from Reference 1 and are empirical in nature.

Section 3.1 is subdivided as follows:

Section 3.1.1 Lift Increment Due to Wing-Mounted Store Installations

Section 3.1.2 Lift Increment Due to Fuselage-Mounted Store Installations

Section 3.1.3 Total Lift Increment Due to External Stores

Section 3.1.3 presents the method for computing the total incremental lift coefficient due to symmetric and/or asymmetric loading configurations. That section will then refer the user to Section 3.1.1 and/or Section 3.1.2 as appropriate for the loading configuration being analyzed. Due to the nature of the method, the lift increments for wing and fuselage stores are computed separately for pairs of symmetrically-mounted store installations by the methods of Sections 3.1.1 and 3.1.2.

The Datcom methods are applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The methods are limited to the store-loading configurations and Mach-number ranges presented in Table 3.1-A. The methods are applicable to mixed loading configurations obtained by combining two or more loadings specified in Table 3.1-A. Additional limitations are specifically noted in each of the sections.

TABLE 3.1-A

LOADING AND MACH-NUMBER LIMITATIONS

Mounting Location	Carriage Mode	Mount/Loading Type	Mach-Number Range
Wing	Single	Pylon – Empty	0 → 2.0
		Pylon – Store	
	Multiple	Pylon – Empty MER	0 → 1.6
		Pylon – Full/Partial MER	
		Pylon – Empty TER	
		Pylon – Full/Partial TER	
Fuselage	Single	Tangent	0 → 2.0
		Pylon – Empty	
		Pylon – Store	
	Multiple	Tangent – Empty MER	0 → 1.6
		Tangent – Full/Partial MER	
		Tangent – Empty TER	
		Tangent – Full/Partial TER	
		Pylon – Empty MER	
		Pylon – Full/Partial MER	
		Pylon – Empty TER	
		Pylon – Full/Partial TER	

For most configurations the addition of wing-mounted stores results in a loss of aircraft lift in the subsonic-flight regime. The lift loss generally increases substantially through the transonic speed range, and often reverses to provide positive-lift increments at the higher supersonic speeds ($M > 1.6$).

REFERENCE

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

3.1.1 LIFT INCREMENT DUE TO WING-MOUNTED STORE INSTALLATIONS

A method is presented in this section for estimating the aircraft lift-coefficient increment due to wing-mounted store installations. The method as presented is for estimating the increment due to a pair of symmetric wing-mounted installations. The increment due to a single installation may also be obtained by simply using half the increment due to the pair of symmetric installations.

For most configurations the addition of wing-mounted stores results in a loss of aircraft lift in the subsonic speed range. The lift loss generally increases substantially through the transonic speed range, and often reverses to provide positive lift increments at the higher supersonic speeds.

The Datcom method is taken from Reference 1 and is empirical in nature. The method is applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The limitations on configuration and Mach-number range are summarized in Table 3.1-A of the preceding section. Additional limitations and assumptions pertaining to the method are listed below:

1. The method is not applicable to wing-tip or wing-tangent-mounted stores.

2. The method has been verified for a Mach-number range between $M = 0.6$ and $M = 2.0$ with a few exceptions. Caution should be used in extrapolating the empirical curves beyond the given Mach-number range.

3. The method has not been verified for configurations in which flaps, slats or other flow disrupting devices are deployed.

4. The method gives the best results for an angle-of-attack range from 0 to 8°, although the method can be used for higher angles of attack.

5. The data base used in deriving the method relied heavily on swept-wing tactical-combat-aircraft wind-tunnel data.

6. No method is provided to estimate fuselage and adjacent-store interference effects. These effects may be significant if the separation distances are less than 3 store diameters. Proximity to engine inlets may also be significant.

7. The method is applicable for sideslip angles less than 4°.

The loading configuration capabilities of the method are given in Table 3.1.1-A. Each configuration is assigned a number which is referred to throughout the method. The method is applied separately to each single store installation or symmetrical pair of store installations.

TABLE 3.1.1-A

STORE CONFIGURATION SUMMARY

Configuration			Configuration Number
Mounting	Carriage	Loading	
Pylon	None	Empty	1
	Single	Single	1
Pylon	MER	Empty	2
		Partially Loaded	2
		Full	2
Pylon	TER	Empty	3
		Partially Loaded	3
		Full	3

A. SUBSONIC

DATCOM METHOD

The incremental lift coefficient, based on wing reference area, due to a pair of symmetric wing-mounted external-store installations is given by Equation 3.1.1-a. (For a single installation, this value should be divided by two.)

$$\Delta C_{L_{WS}} = \frac{1}{S_W}\left[(L_R + L_{LE} K_{AWA})(K_A K_p + K_f) + L_{\alpha_{WS}}(\alpha - 4.0)\right] \qquad 3.1.1\text{-a}$$

where

S_W is the wing reference area (ft^2).

L_R is an incremental-lift effect due to carriage-rack installation.

For an empty pylon or a pylon-mounted, single-store installation (Configuration 1) L_R is presented over the Mach-number range from 0.6 through 2.0 in Figure 3.1.1-12.

For MER store loading (Configuration 2) or TER store loading (Configuration 3) L_R is presented at M = 0.6, 0.8, and 1.6 in Figures 3.1.1-13 and 3.1.1-14. The value of L_R between M = 0.6 and 0.8 may be obtained by linear interpolation. L_R at M = 1.6 is a single-point value. Over the Mach-number range from $M > 0.8$ to $M < 1.6$, $L_R = 0$ for Configurations 2 and 3.

The term L_R is presented on Figures 3.1.1-12 through 3.1.1-14 as a function of S_{W_a}

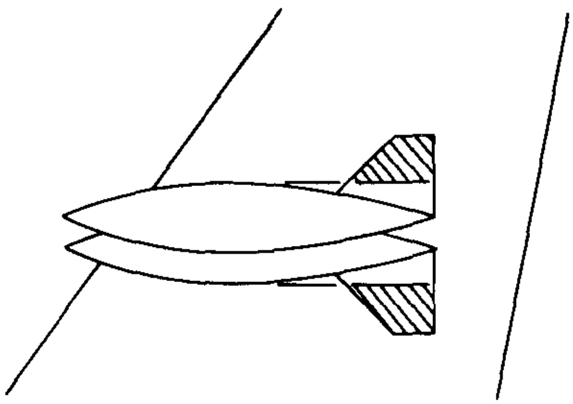
where

S_{W_a} is the affected wing area (in.^{2}) of both wings and is given by

$$S_{W_a} = 2\left(S_{W_{a_B}} + S_{W_{a_F}}\right) \qquad 3.1.1\text{-b}$$

where

$S_{W_{a_F}}$ is the vertically projected area (in.^{2}) on one wing of the unobstructed, exposed-fin areas of the stores at the given store station for one installation (See Sketch (a).).



SKETCH (a)

$S_{W_{a_B}}$ is the pseudo-store-body or pylon vertically projected area (in.^{2}) on one wing given by the following geometrical relationships:

1. For $x_{FWD} \geqslant 0$ and $c \geqslant (\ell_{SP} + x_{FWD})$:

$$S_{W_{a_B}} = \ell_{SP} d_w \qquad 3.1.1\text{-c}$$

2. For $x_{FWD} \geqslant 0$ and $c \leqslant (\ell_{SP} + x_{FWD})$:

$$S_{W_{a_B}} = (c - x_{FWD}) d_w \qquad 3.1.1\text{-d}$$

3. For $x_{FWD} < 0$ and $c < (\ell_{SP} + x_{FWD})$:

$$S_{W_{a_B}} = c d_w \qquad 3.1.1\text{-e}$$

4. For $x_{FWD} < 0$ and $c \geqslant (\ell_{SP} + x_{FWD})$:

$$S_{W_{a_B}} = (\ell_{SP} + x_{FWD}) d_w \qquad 3.1.1\text{-f}$$

where

x_{FWD} is the longitudinal distance (in.) from the local wing leading edge to the store/pylon nose, positive for store/pylon nose aft of the leading edge. (See Sketch (b).)

c is the local-wing chord (in.) at the store or pylon station. (See Sketch (b).)

ℓ_{SP} is the maximum store/pylon installation length (in.). (See Sketch (b).)

d_w is the defined width (in.) of the store installation, not including protruding fins, given by

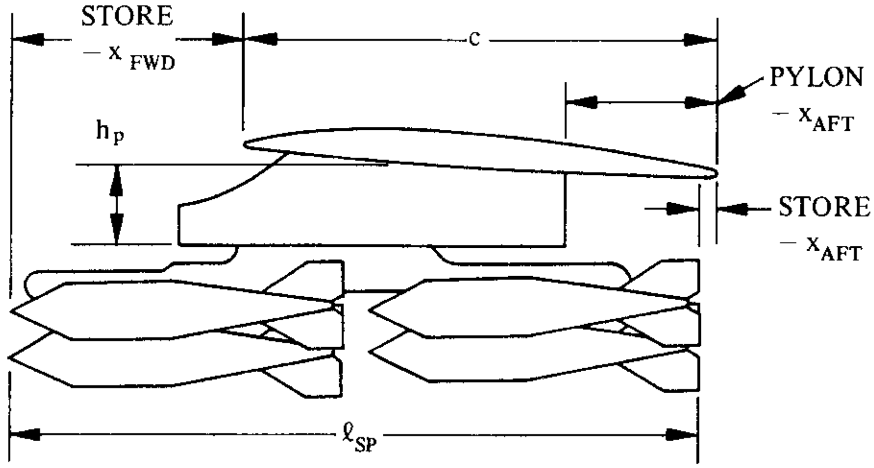
1. For an empty pylon:

$$d_w = 1.5 \text{ (maximum pylon width)} \qquad 3.1.1\text{-g}$$

2. For a single store:

$$d_w = d_S \qquad 3.1.1\text{-h}$$

(d_S is the maximum store diameter)



SKETCH (b)

L_{LE} is an incremental-lift effect of the longitudinal location of multiple-mounted stores along the local wing chord. For Configuration 1, $L_{LE} = 0$. For Configurations 2 and 3 $L_{LE} = 0$ at $M \leqslant 0.8$ and at $M = 1.6$. Over the Mach-number range from $M > 0.8$ to $M < 1.6$ L_{LE} is obtained from Figures 3.1.1-15 and 3.1.1-16 as a function of x_{AFT}/c. The value of x_{AFT} is the longitudinal distance (in.) from the local wing trailing edge to the trailing edge of the store installation (or pylon trailing edge for the empty pylon case), positive in the aft direction. (See Sketch (b).)

K_{AWA} is the longitudinal-location factor for multiple-rack carriage (Configurations 2 and 3) obtained from Figure 3.1.1-17. ($K_{AWA} = 0$ at $M \leqslant 0.8$ and at $M = 1.6$.)

K_{Λ} is the wing-sweep-effect parameter obtained from Figure 3.1.1-18a.(This parameter is a function of the wing leading-edge sweep angle Λ_{LE}.)

K_p is the pylon-height-effect parameter given by

$$K_p = 1 + K_H K_X K_W \qquad 3.1.1\text{-i}$$

where

K_H is a pylon-height factor obtained from Figure 3.1.1-18b as a function of the average pylon height, h_p (in.). (See Sketch (b).)

K_X is a store-placement factor obtained from Figure 3.1.1-19a as a function of x_{AFT}/c.

K_W is a store-installation-width factor obtained from Figure 3.1.1-19b as a function of h_p/d_w.

K_f is the fuselage proximity-effect parameter where

$$K_f = K_{HF} K_{VF} \qquad 3.1.1\text{-j}$$

and

K_{HF} is a lateral store-to-fuselage clearance parameter obtained from Figure 3.1.1-20b.

K_{VF} is a vertical clearance parameter obtained from Figure 3.1.1-20a.

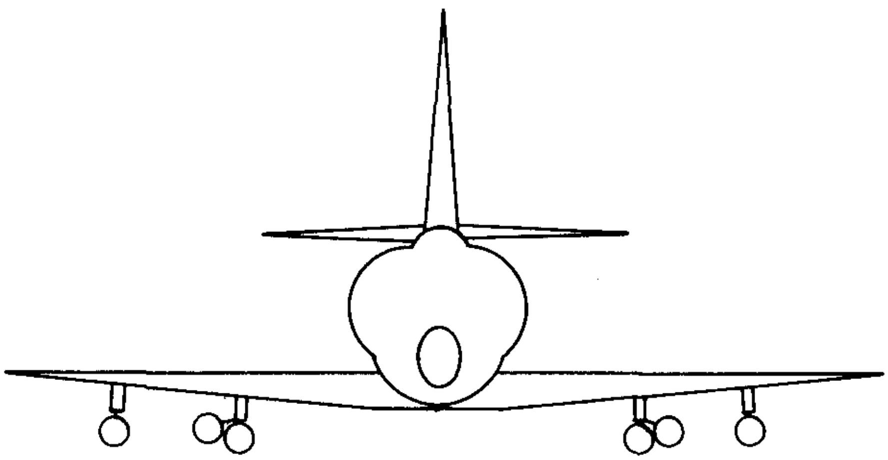
Note that for a low-wing configuration $K_{HF} = K_{VF} = 0$.

$L_{\alpha_{WS}}$ is an effect due to aircraft angle of attack obtained from Figures 3.1.1-21a through -21h as a function of store-installation type, Mach number, and x_{AFT}/c.

α is the aircraft angle of attack (deg).

Sample Problem

Given: A swept-wing subsonic fighter aircraft from Reference 2, symmetrically loaded as follows:



FRONT VIEW

Spanwise Station	Rack Type	Mounting	Store Type	No. of Stores	Configuration Number (Table 3.1.1-A)
Inboard Wing	TER	Pylon	500-lb Bomb	2	3
Outboard Wing	Single	Pylon	500-lb Bomb	1	1

Aircraft Data:

$S_W = 260 \text{ ft}^2$ $\qquad$ $c = 121.5$ in. (at inboard sta.)

$\Lambda_{LE} = 42^o$ $\qquad$ $c = 37.8$ in. (at outboard sta.)

Stores Data:

$d_S = 12$ in. $\qquad$ $\ell_{SP} = 91.2$ in.

Installation Data:

Location	d_w	$\frac{x_{AFT}}{c}$	$\frac{x_{FWD}}{c}$	h_p	ℓ_{SP}
Inboard Wing	25.6 in.	–0.400	–0.158	11.2 in.	91.2 in.
Outboard Wing	12 in.	–0.210	–0.264	11.2 in.	91.2 in.

Additional Data:

$M = 0.8$ $\qquad\qquad$ $\alpha = 8^{\circ}$

Geometry of unobstructed, exposed-fin areas required for calculation of $S_{W_{a_F}}$ is shown below

Compute $\Delta C_{L_{WS}}$ for the inboard wing station (Configuration 3):

$$\ell_{SP} + x_{FWD} = \ell_{SP} + \frac{x_{FWD}}{c} c$$

$$= 91.2 + (-0.158)(121.5)$$

$$= 72.0 \text{ in.}$$

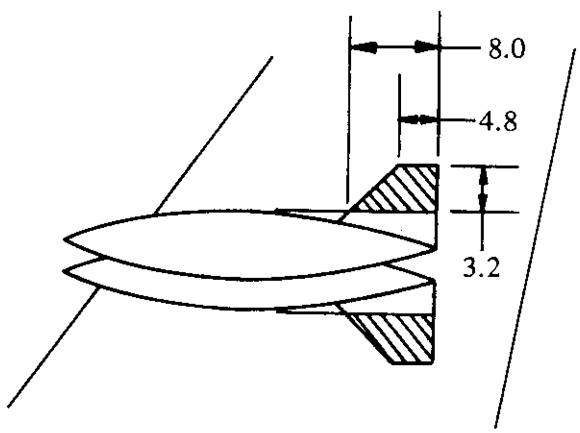
Since $x_{FWD} < 0$ and $c \geqslant \ell_{SP} + x_{FWD}$

$$S_{W_{a_B}} = (\ell_{SP} + x_{FWD})d_w \qquad \text{(Equation 3.1.1-f)}$$

$$= (72.0)(25.6)$$

$$= 1843 \text{ in.}^2$$

To compute $S_{W_{a_F}}$, refer to the planform sketch below of the inboard wing installation:



$S_{W_{a_F}}$ is the shaded area of the fins not included in the $S_{W_{a_B}}$ computation.

$$S_{W_{a_F}} = (2)\left(\frac{8.0 + 4.8}{2}\right)(3.2)$$

$$= 41 \text{ in.}^2$$

$$S_{W_a} = 2\left(S_{W_{a_B}} + S_{W_{a_F}}\right) \qquad \text{(Equation 3.1.1-b)}$$

$$= 2\ (1843 + 41)$$

$$= 3768 \text{ in.}^2$$

$L_R = -4.7$ (Figure 3.1.1-14, Configuration 3)

$L_{LE} = 0\ (M \leqslant 0.8)$

$K_{AWA} = 0\ (M \leqslant 0.8)$

$K_\Lambda = 1.0$ (Figure 3.1.1-18a)

$K_H = -0.124$ (Figure 3.1.1-18b)

$K_X = 0.30$ (Figure 3.1.1-19a)

$$\frac{h_p}{d_w} = \frac{11.2}{25.6}$$

$$= 0.438$$

$K_W = 1.145$ (Figure 3.1.1-19b)

$K_p = 1 + K_H K_X K_W$ (Equation 3.1.1-i)

$$= 1 + (-0.124)(0.30)(1.145)$$

$$= 0.957$$

$K_{HF} = 0,\qquad K_{VF} = 0$ (low-wing configuration)

$K_f = K_{HF} K_{VF} = 0$ (Equation 3.1.1-j)

$L_{\alpha_{WS}} = 0.43$ (Figure 3.1.1-21b)

Solution:

$$\Delta C_{L_{WS}} = \frac{1}{S_W}\left[(L_R + L_{LE}K_{AWA})(K_A K_p + K_f) + L_{\alpha_{WS}}(\alpha - 4.0)\right] \qquad \text{(Equation 3.1.1-a)}$$

$$= \frac{1}{260}\left\{[-4.7 + (0)(0)]\,[(1.0)(0.957) + 0] + (0.43)(8.0 - 4.0)\right\}$$

$$= -0.0107 \text{ (inboard wing station)}$$

Compute $\Delta C_{L_{WS}}$ for the outboard wing station (Configuration 1):

$$\ell_{SP} + x_{FWD} = \ell_{SP} + \frac{x_{FWD}}{c}\,c$$

$$= 91.2 + (-0.264)(87.8)$$

$$= 68.0 \text{ in.}$$

Since $x_{FWD} < 0$ and $c \geqslant \ell_{SP} + x_{FWD}$

$$S_{W_{a_B}} = (\ell_{SP} + x_{FWD})d_w \qquad \text{(Equation 3.1.1-f)}$$

$$= (68.0)(12.0)$$

$$= 816 \text{ in.}^2$$

As in the case of the inboard installation, trapezoidal areas of 2 fins extend beyond the projected store body area, $S_{W_{a_B}}$. Since the stores are identical,

$$S_{W_{a_F}} = 41 \text{ in.}^2 \text{ (previously calculated)}$$

$$S_{W_a} = 2\left(S_{W_{a_B}} + S_{W_{a_F}}\right) \qquad \text{(Equation 3.1.1-b)}$$

$$= 2\,(816 + 41)$$

$$= 1714 \text{ in.}^2$$

$$L_R = -0.8 \qquad \text{(Figure 3.1.1-12, Configuration 1)}$$

$$L_{LE} = 0 \text{ (Configuration 1)}$$

$$K_{AWA} = 0 \text{ (Applicable for multiple-rack carriage only)}$$

$K_\Lambda \quad = 1.0 \qquad$ (Figure 3.1.1-18a)

$K_H \quad = -0.124 \qquad$ (Figure 3.1.1-18b)

$K_X \quad = 0.68 \qquad$ (Figure 3.1.1-19a)

$$\frac{h_p}{d_w} = \frac{11.2}{12.0} = 0.93$$

$K_W \quad = 0.175 \qquad$ (Figure 3.1.1-19b)

$$K_p = 1 + K_H K_X K_W \qquad \text{(Equation 3.1.1-i)}$$

$$= 1 + (-0.124)(0.68)(0.175)$$

$$= 0.985$$

$K_{HF} = K_{VF} = 0$ (low-wing configuration)

$$K_f = K_{HF} K_{VF} = 0 \qquad \text{(Equation 3.1.1-j)}$$

$L_{\alpha_{WS}} = 0.40 \qquad$ (Figure 3.1.1-21b)

Solution:

$$\Delta C_{L_{WS}} = \frac{1}{S_W}\left[(L_R + L_{LE} K_{AWA})(K_\Lambda K_p + K_f) + L_{\alpha_{WS}}(\alpha - 4.0)\right] \qquad \text{(Equation 3.1.1-a)}$$

$$= \frac{1}{260}\left\{[-0.8 + (0)(0)]\,[(1.0)(0.985) + 0] + 0.40\,(8.0 - 4.0)\right\}$$

$$= 0.00312$$

The calculated values of $\Delta C_{L_{WS}}$ at each wing station are combined with fuselage-store increments in the sample problem of Section 3.1.3 to illustrate a complex loading configuration. Comparison of the calculated results with test data is provided in that section.

B. TRANSONIC

The method presented in Paragraph A of this section is also valid in the transonic speed range. The user is cautioned that the accuracy of the method is less than that expected in the subsonic speed range, and test data should be used whenever possible.

C. SUPERSONIC

The method presented in Paragraph A of this section is also valid in the supersonic speed range. The expected accuracy of the method is comparable to that in the subsonic range. The maximum Mach number provided in the design figures indicates the level to which the method is substantiated. Caution should be used when extrapolating the data beyond the Mach range provided in the figures.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer. McDonnell Douglas Corporation Report DAC-67425, 1968. (U)

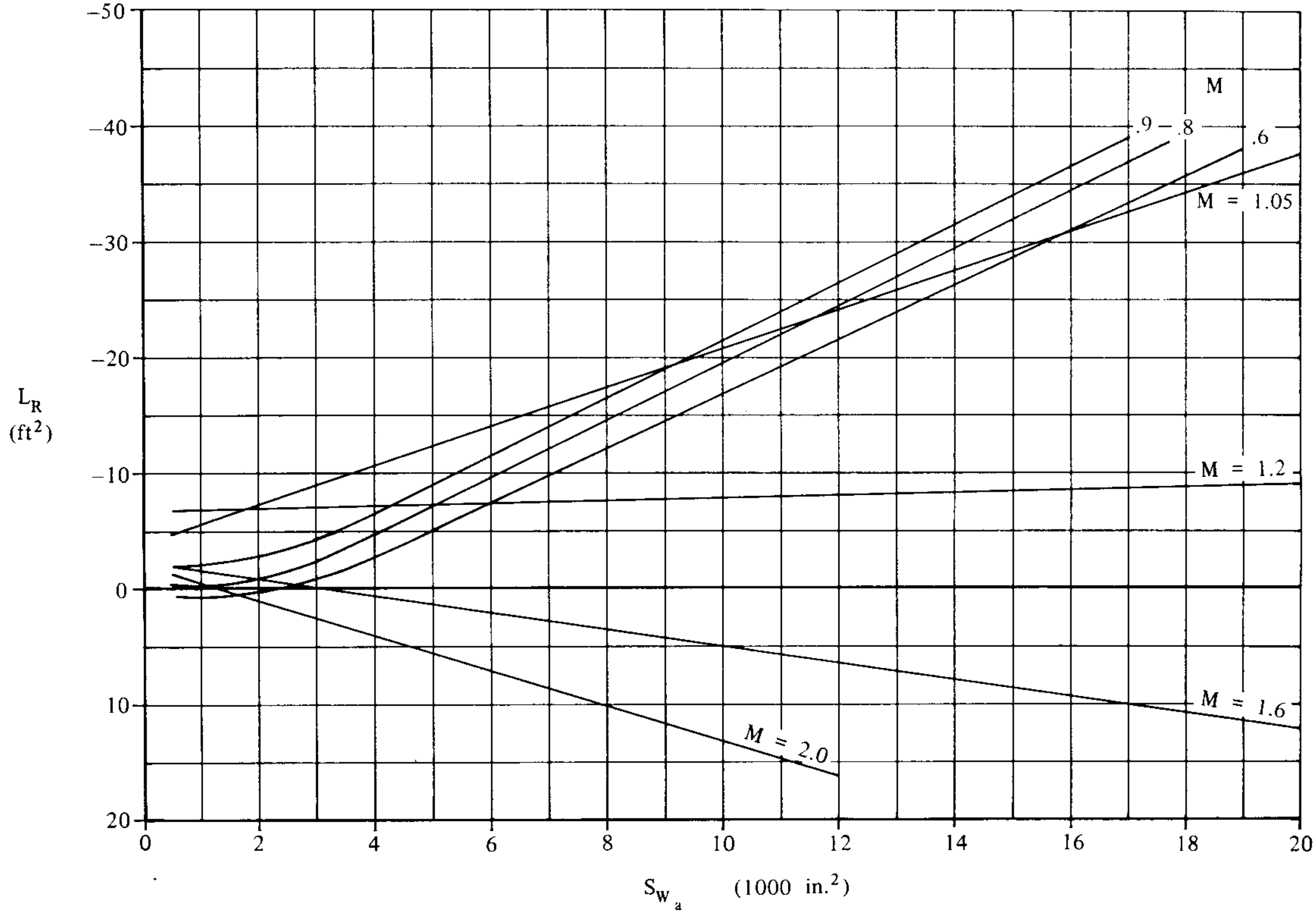


FIGURE 3.1.1-12 INCREMENTAL-LIFT EFFECT DUE TO CARRIAGE-RACK INSTALLATION EMPTY PYLON AND PYLON-MOUNTED SINGLE STORE (CONFIGURATION 1)

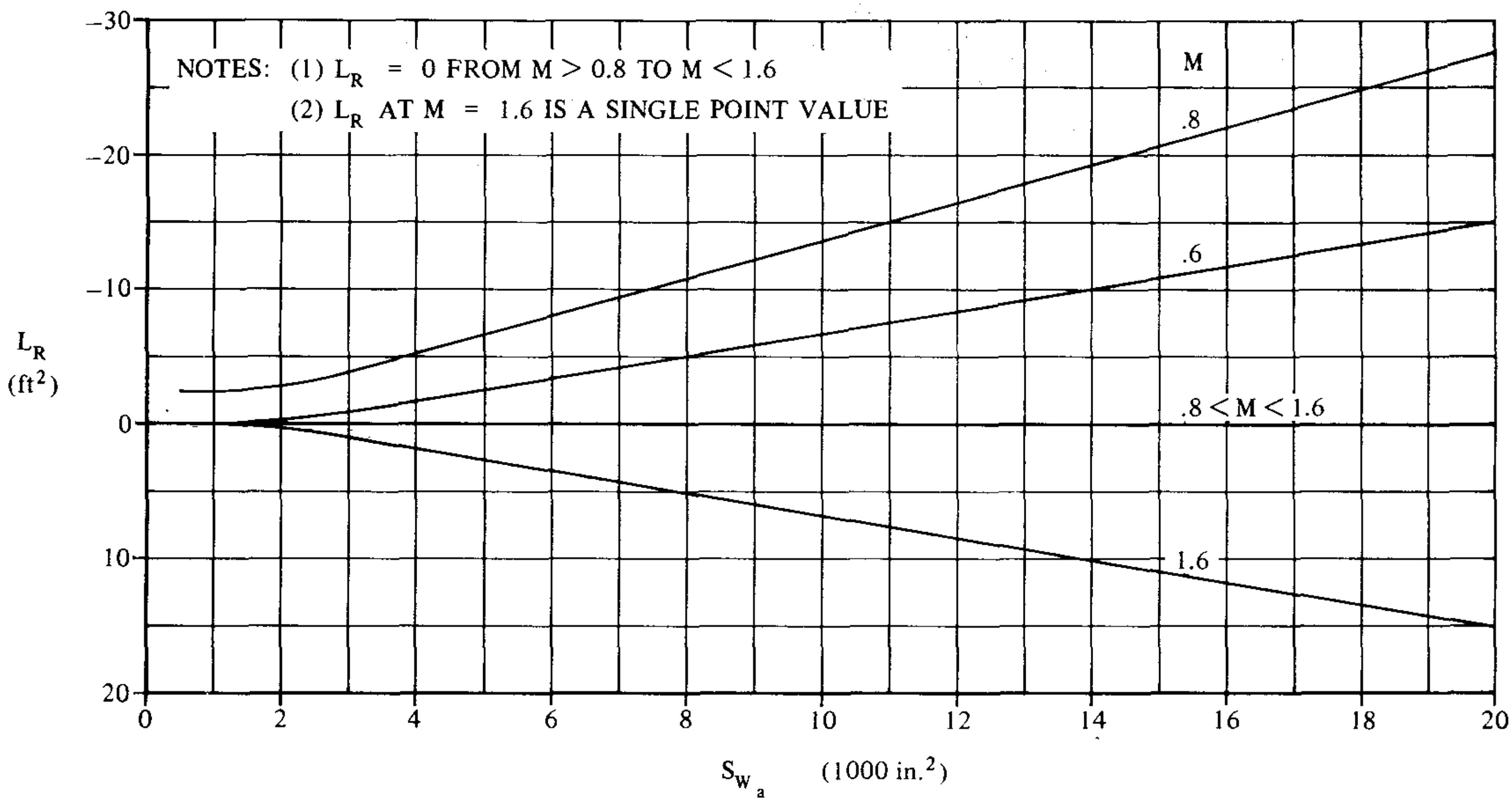


FIGURE 3.1.1-13 INCREMENTAL-LIFT EFFECT DUE TO CARRIAGE-RACK INSTALLATION MER STORE LOADINGS (CONFIGURATION 2)

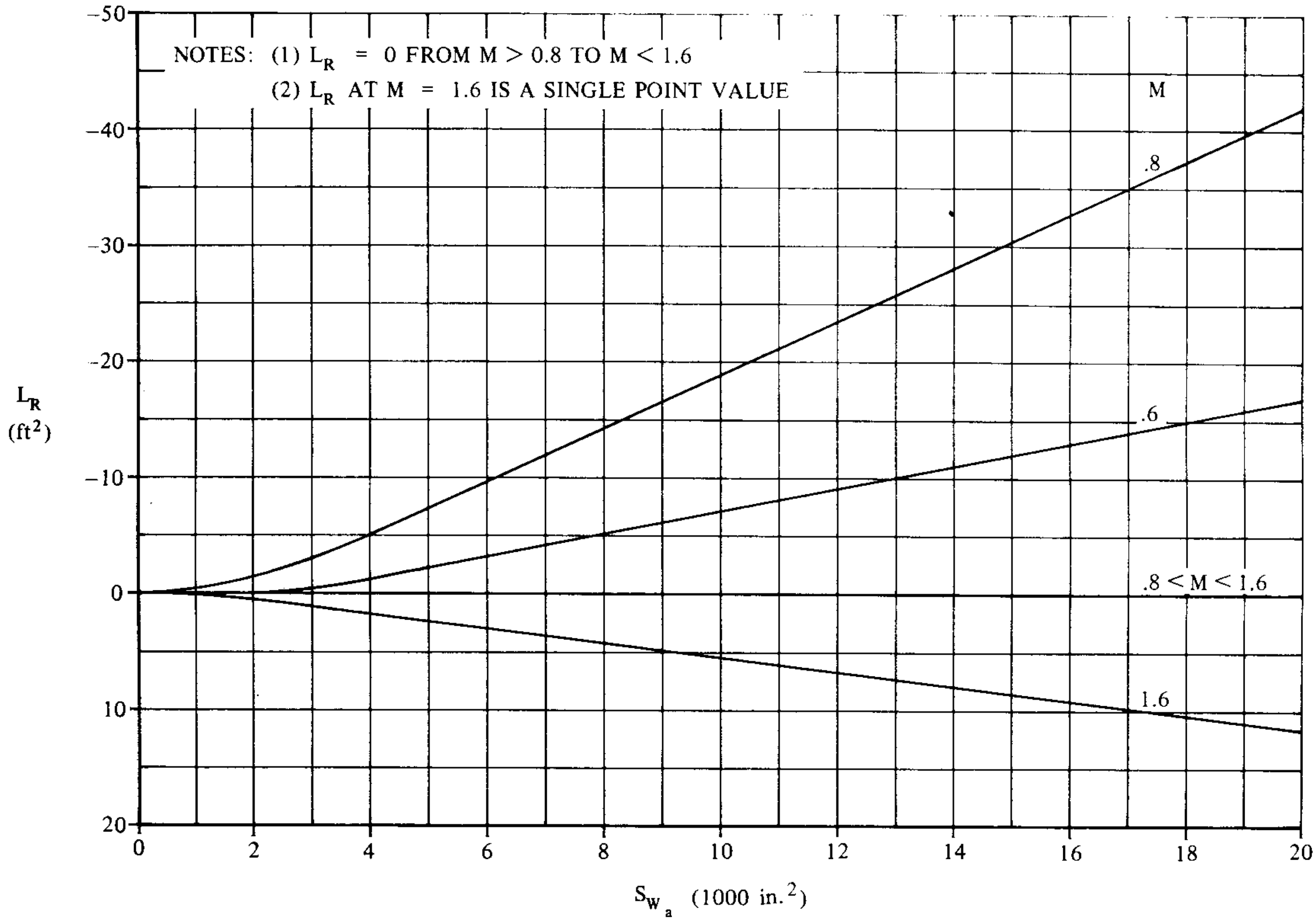


FIGURE 3.1.1-14 INCREMENTAL-LIFT EFFECT DUE TO CARRIAGE-RACK INSTALLATION TER STORE LOADINGS (CONFIGURATION 3)

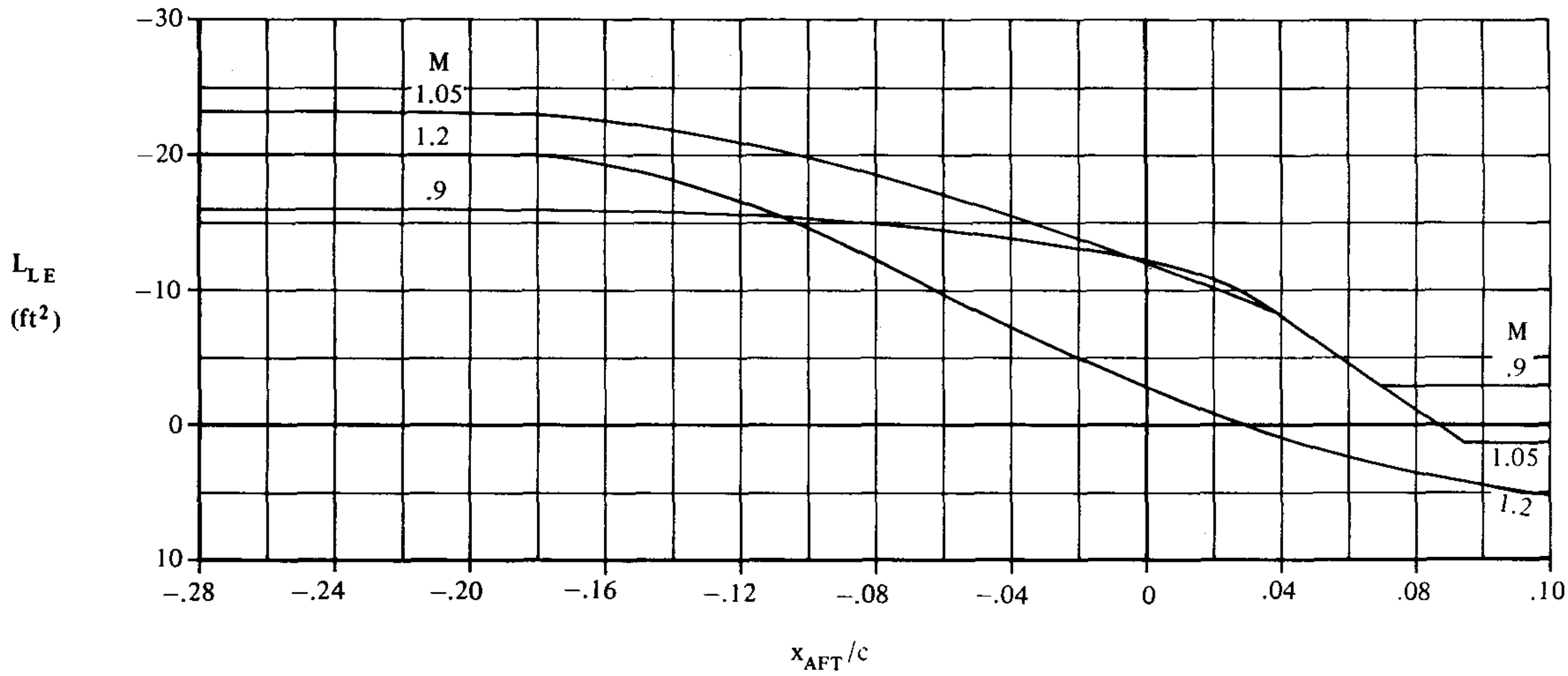


FIGURE 3.1.1-15 INCREMENTAL-LIFT EFFECT DUE TO LONGITUDINAL LOCATION MER STORE LOADINGS (CONFIGURATION 2)

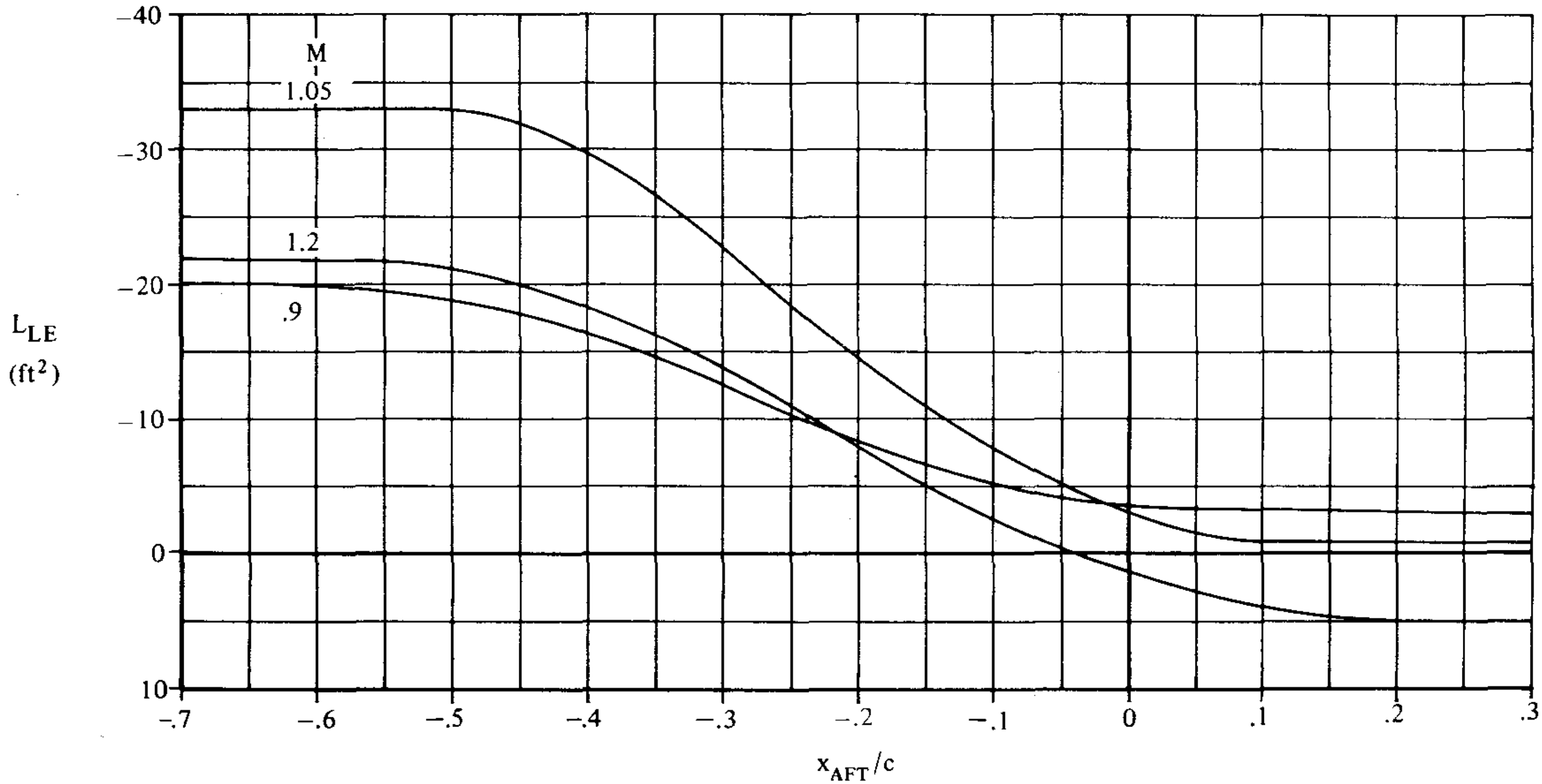


FIGURE 3.1.1-16 INCREMENTAL-LIFT EFFECT DUE TO LONGITUDINAL LOCATION TER STORE LOADINGS (CONFIGURATION 3)

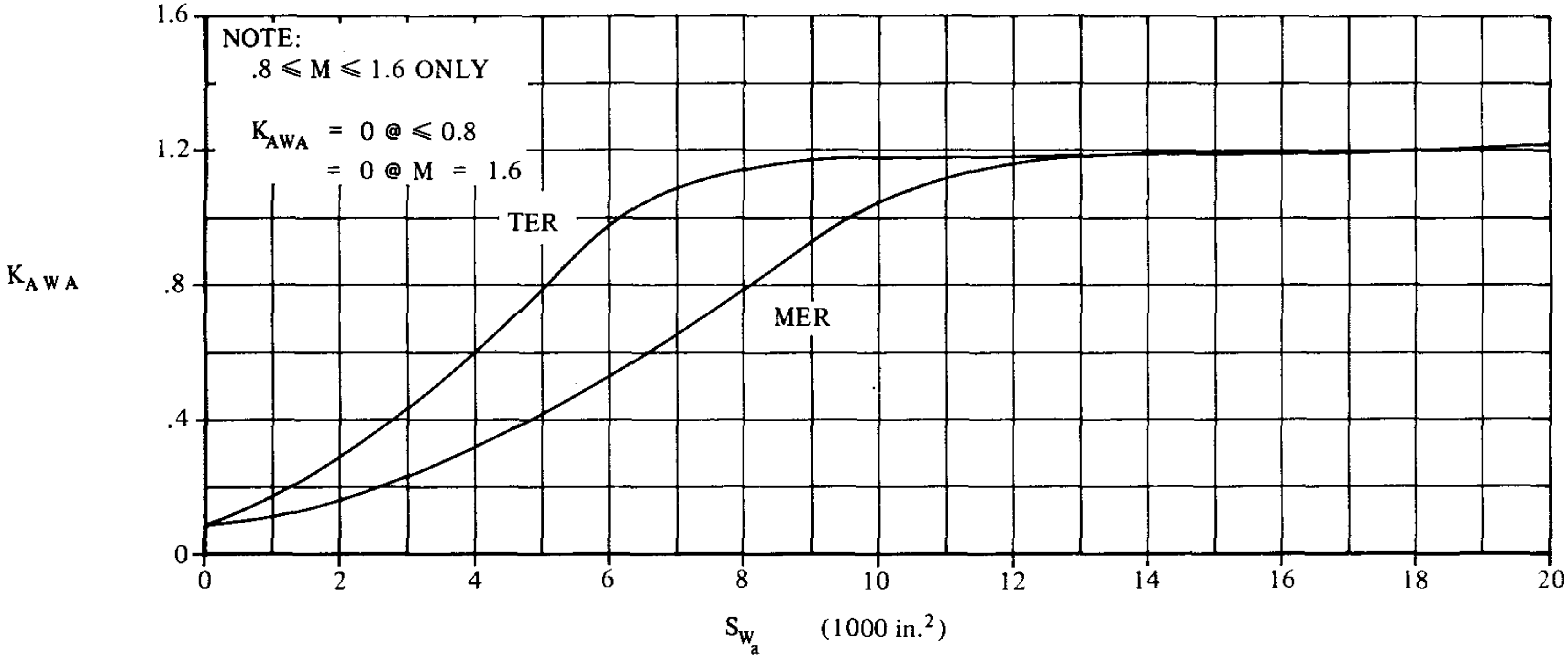


FIGURE 3.1.1-17 EFFECT OF MULTIPLE-RACK TYPE ON LONGITUDINAL-LOCATION FACTOR

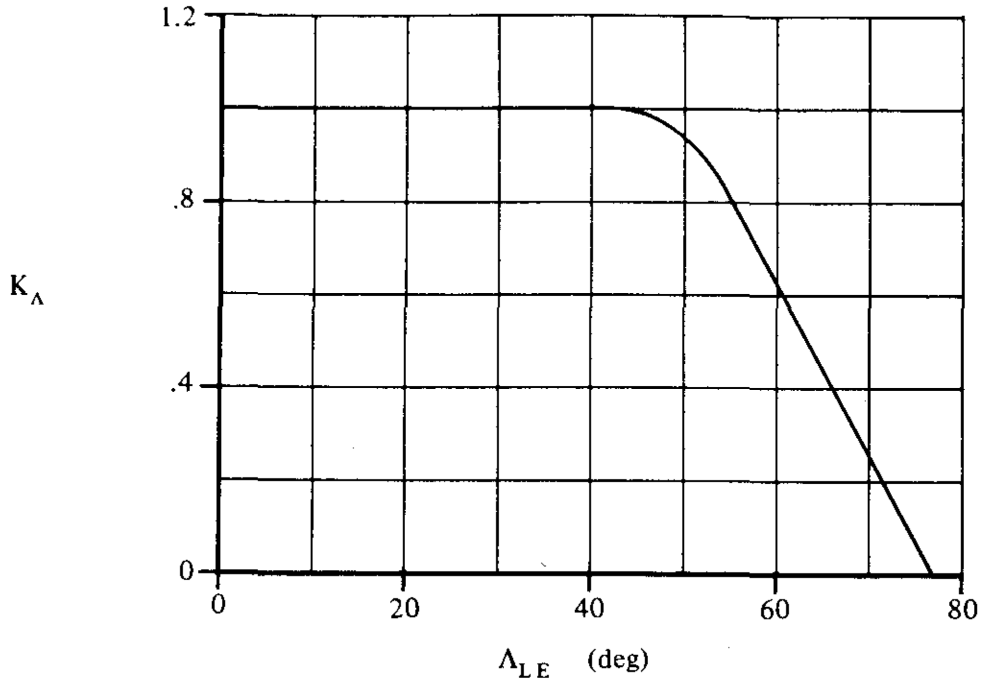


FIGURE 3.1.1-18a WING-SWEEP-EFFECT PARAMETER

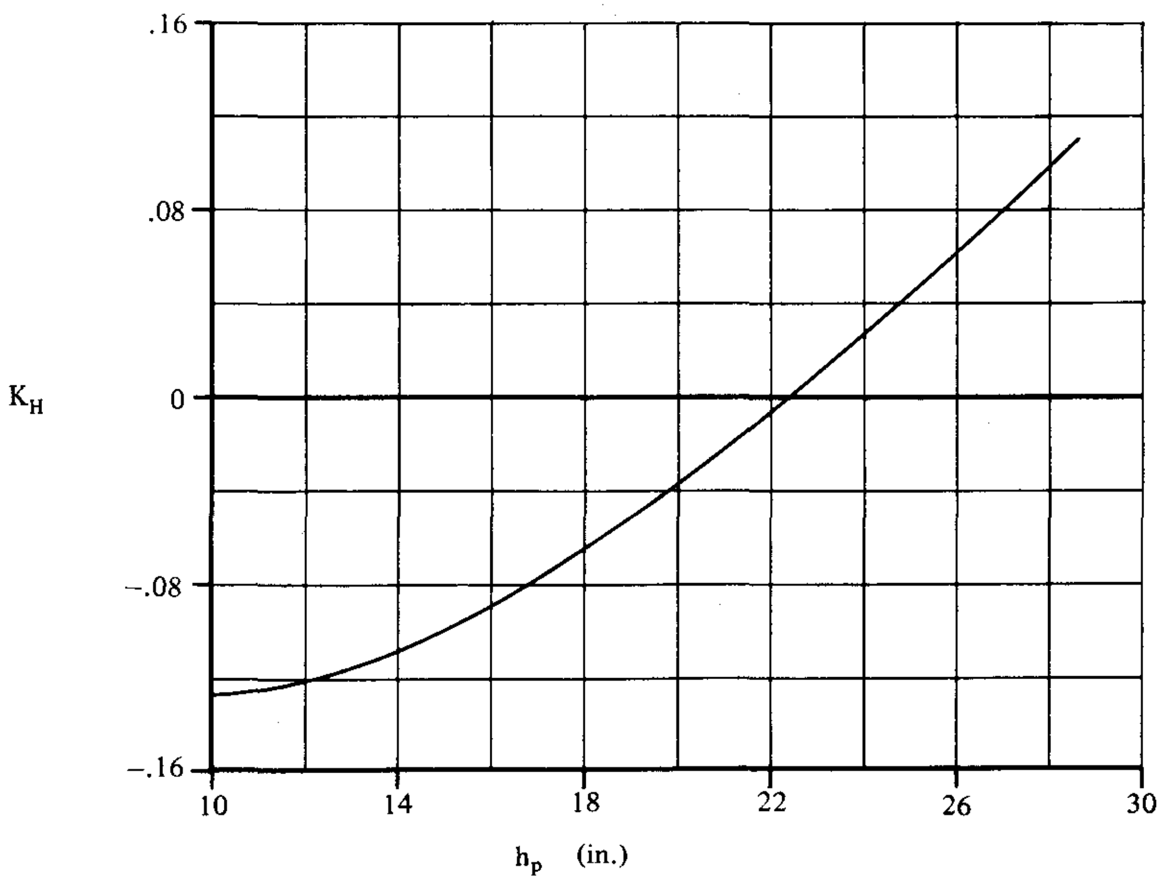


FIGURE 3.1.1-18b PYLON-HEIGHT FACTOR

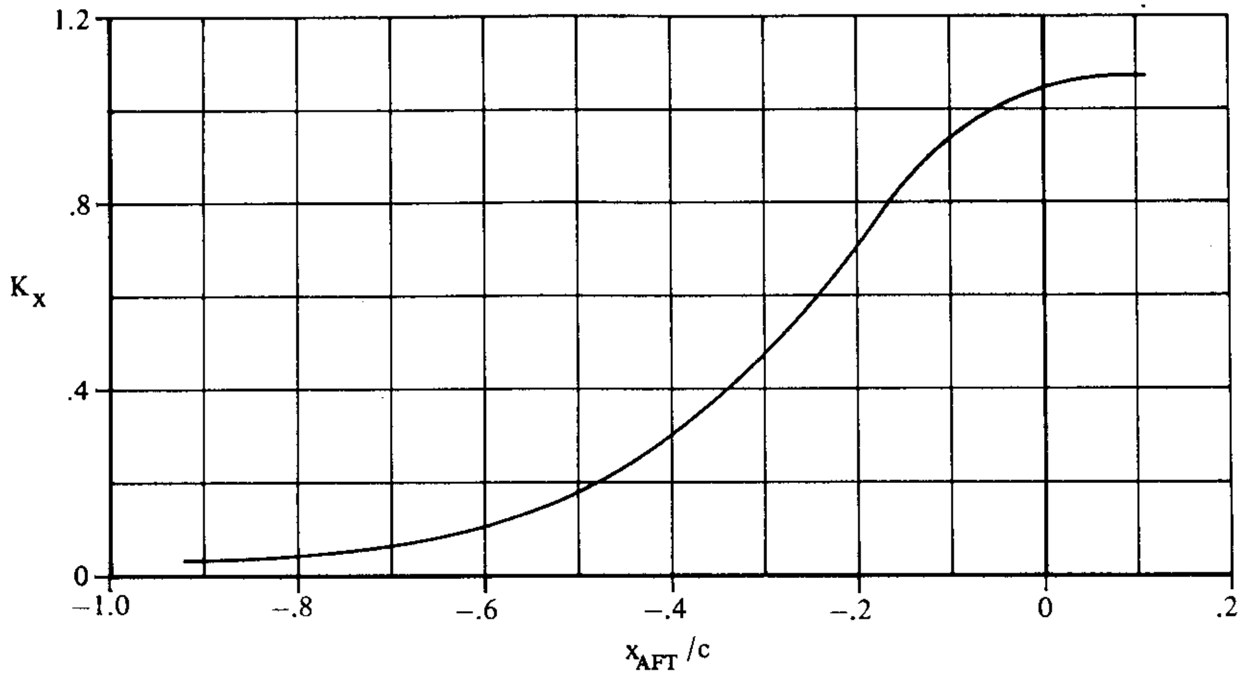


FIGURE 3.1.1-19a STORE-PLACEMENT FACTOR

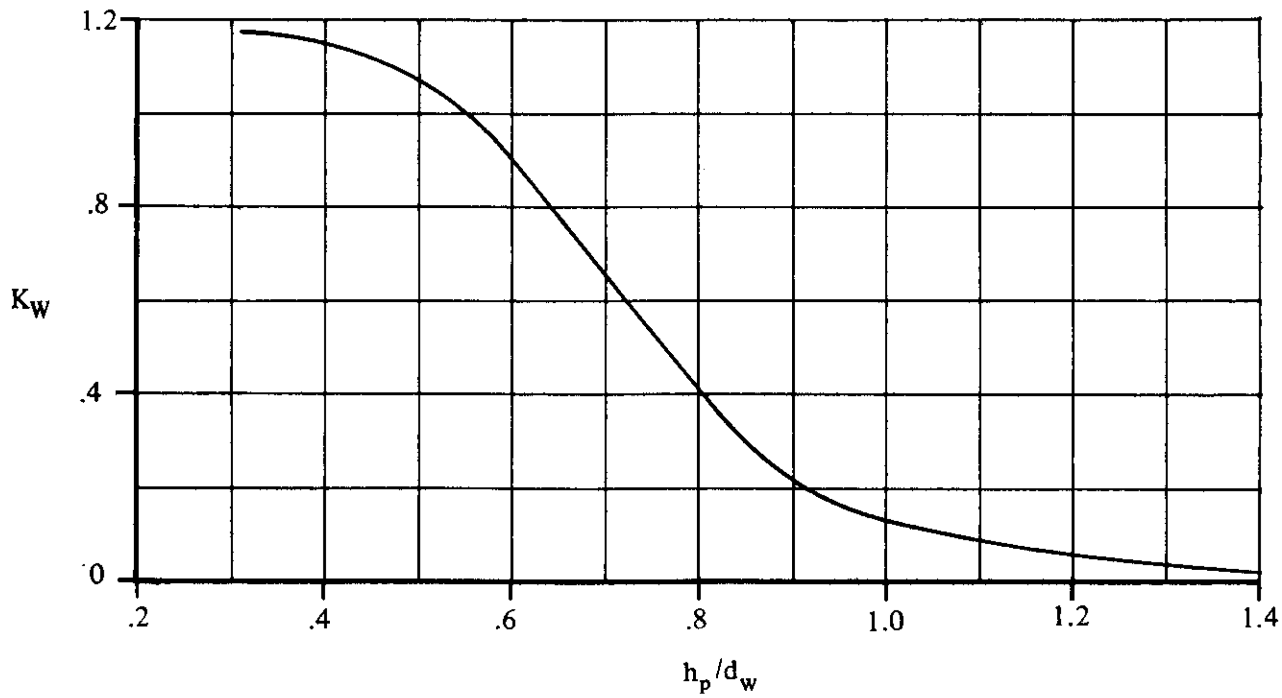


FIGURE 3.1.1-19b STORE-INSTALLATION-WIDTH FACTOR

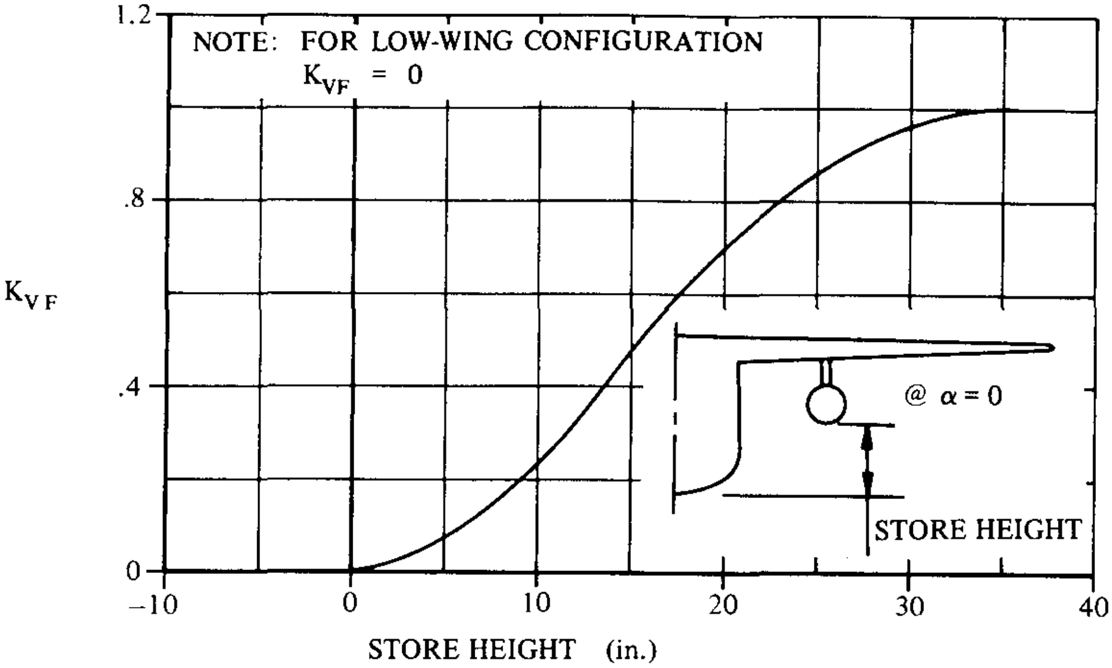


FIGURE 3.1.1-20a VERTICAL CLEARANCE PARAMETER

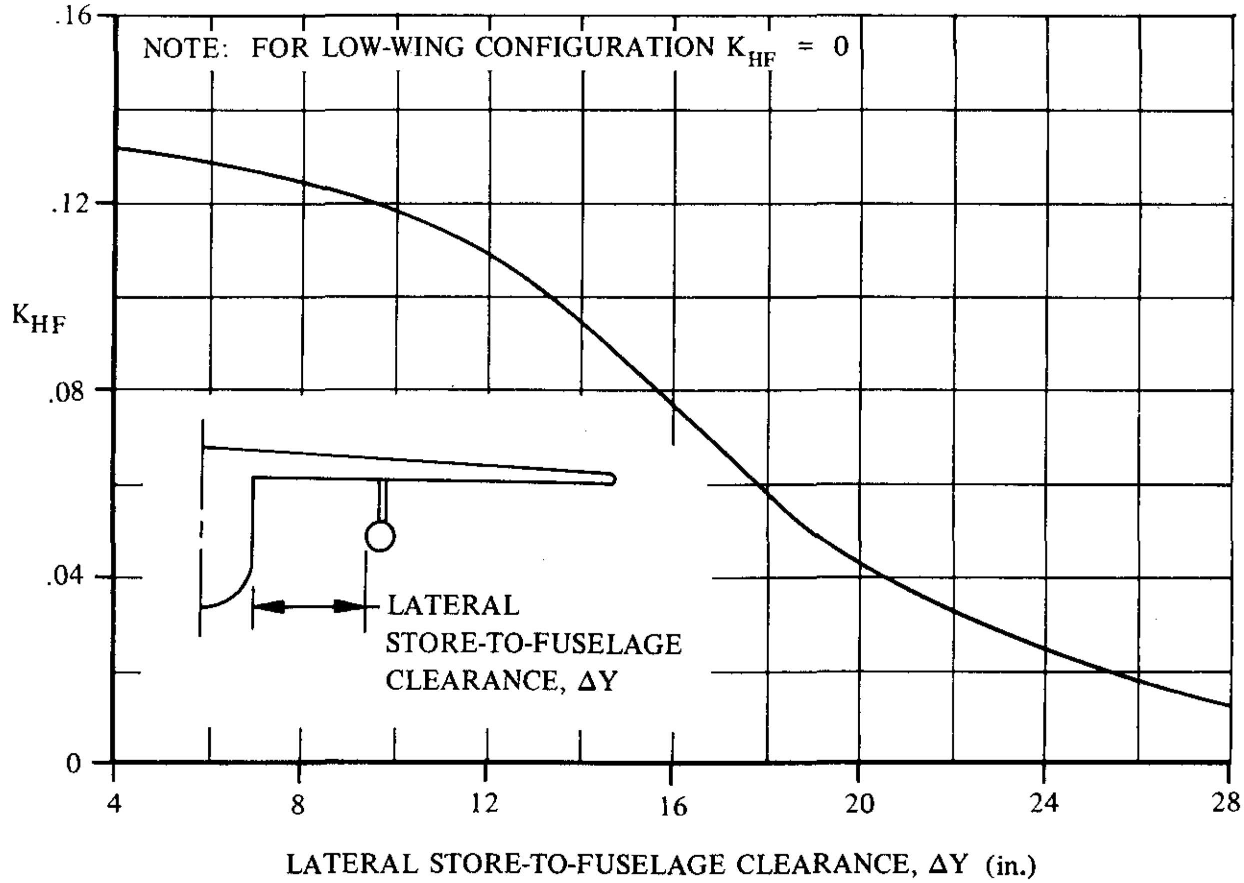


FIGURE 3.1.1-20b LATERAL STORE-TO-FUSELAGE CLEARANCE PARAMETER

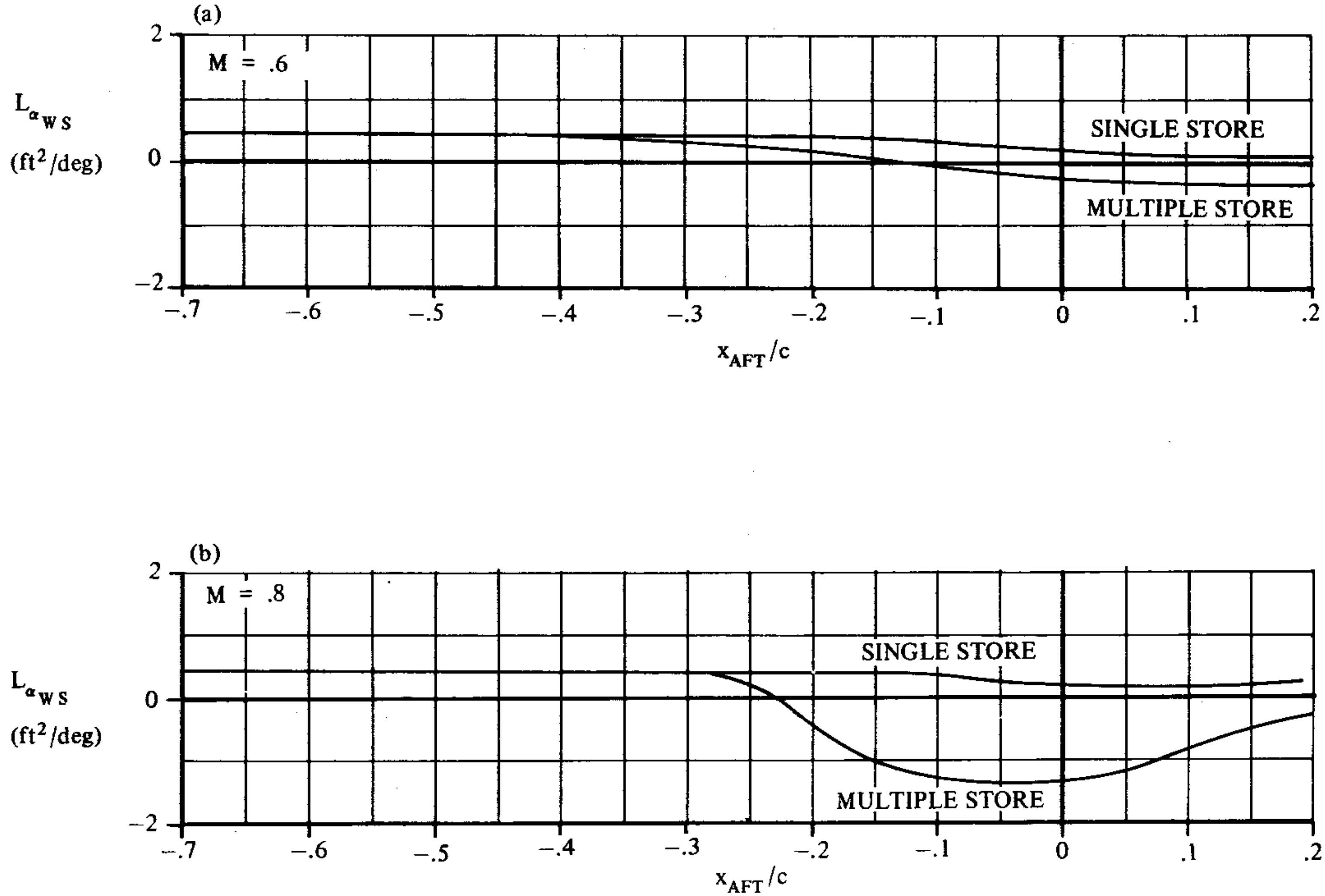


FIGURE 3.1.1-21 INCREMENTAL WING-STORES LIFT EFFECT DUE TO ANGLE OF ATTACK

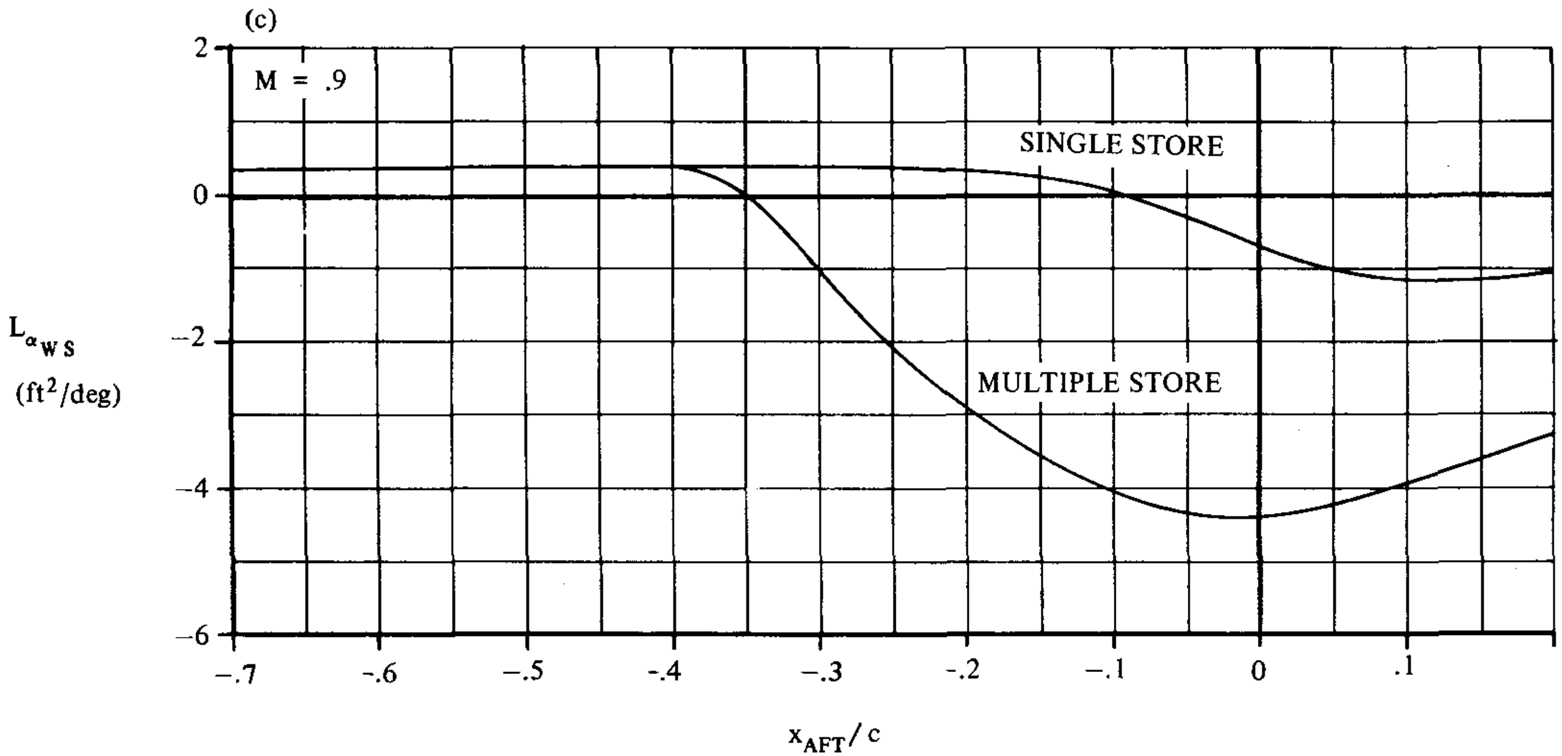


FIGURE 3.1.1-21 (CONTD)

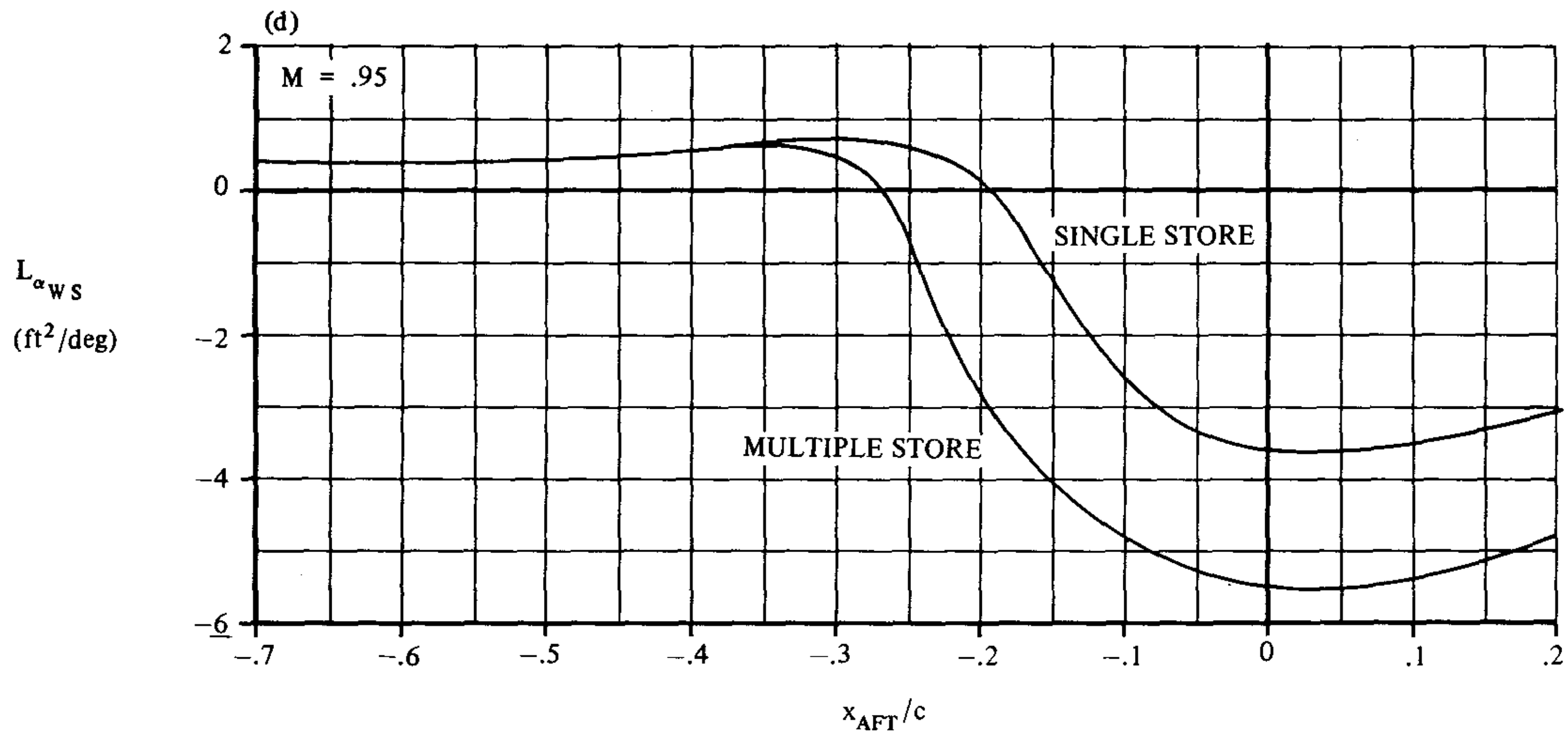


FIGURE 3.1.1-21 (CONTD)

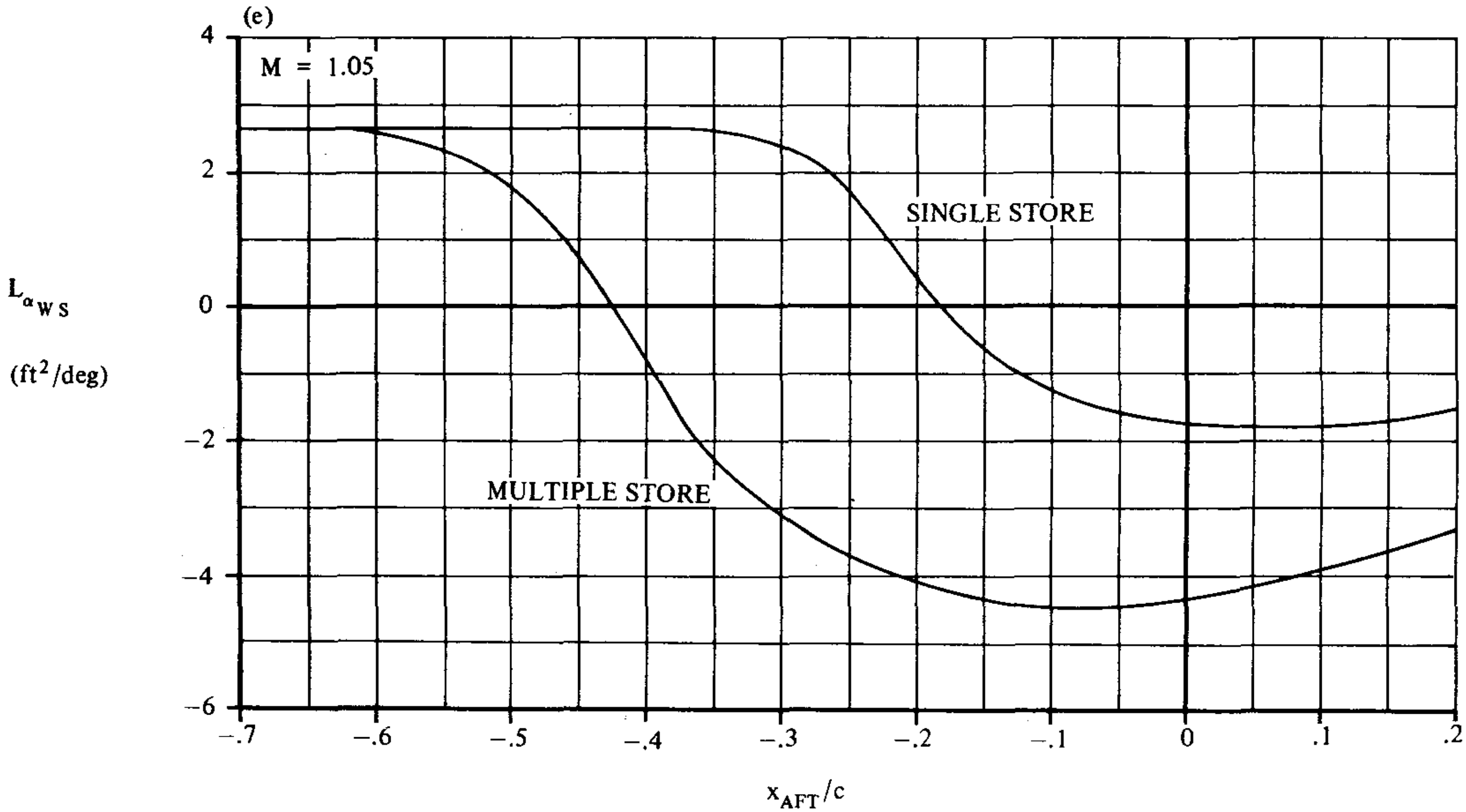


FIGURE 3.1.1-21 (CONTD)

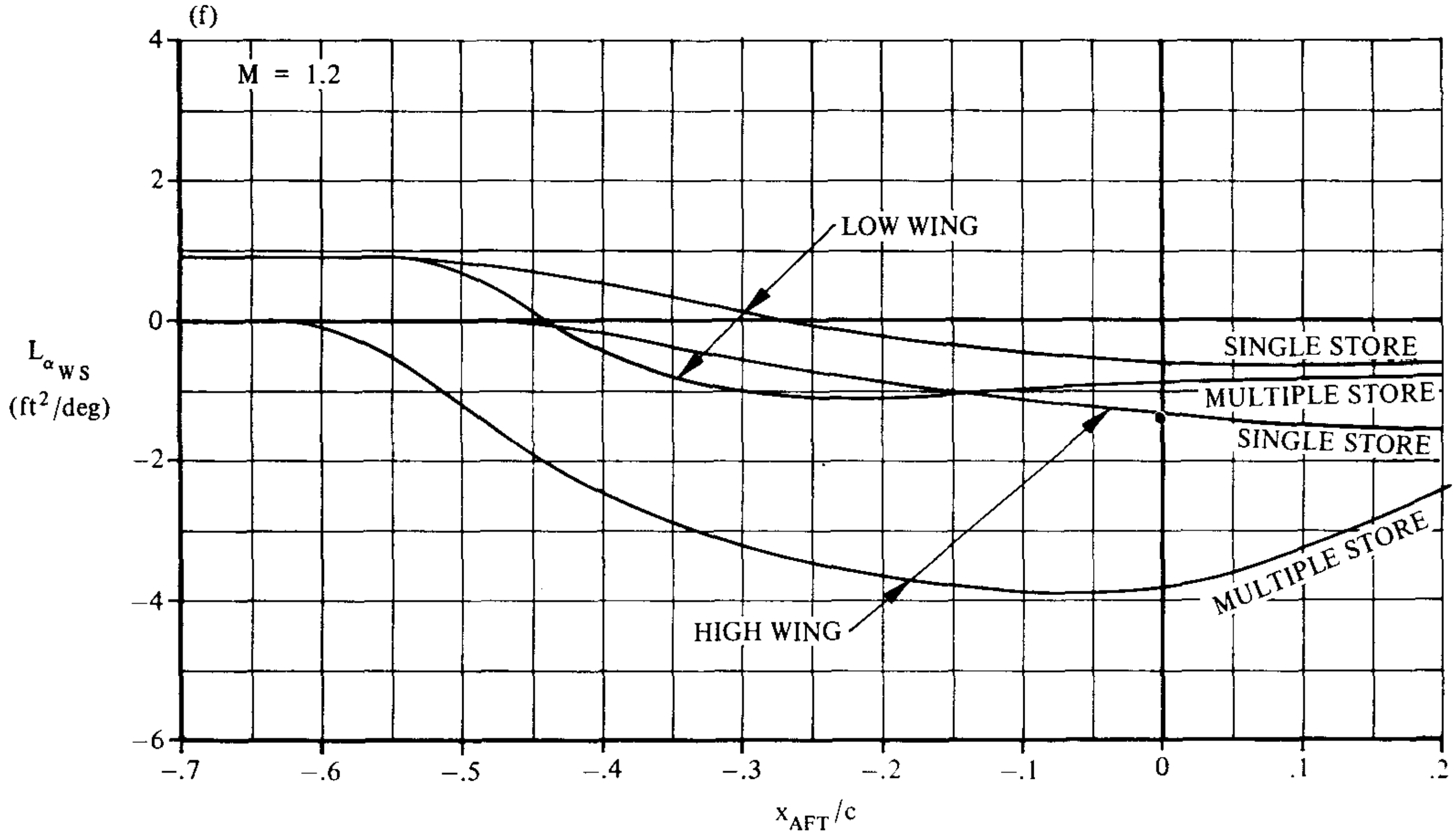
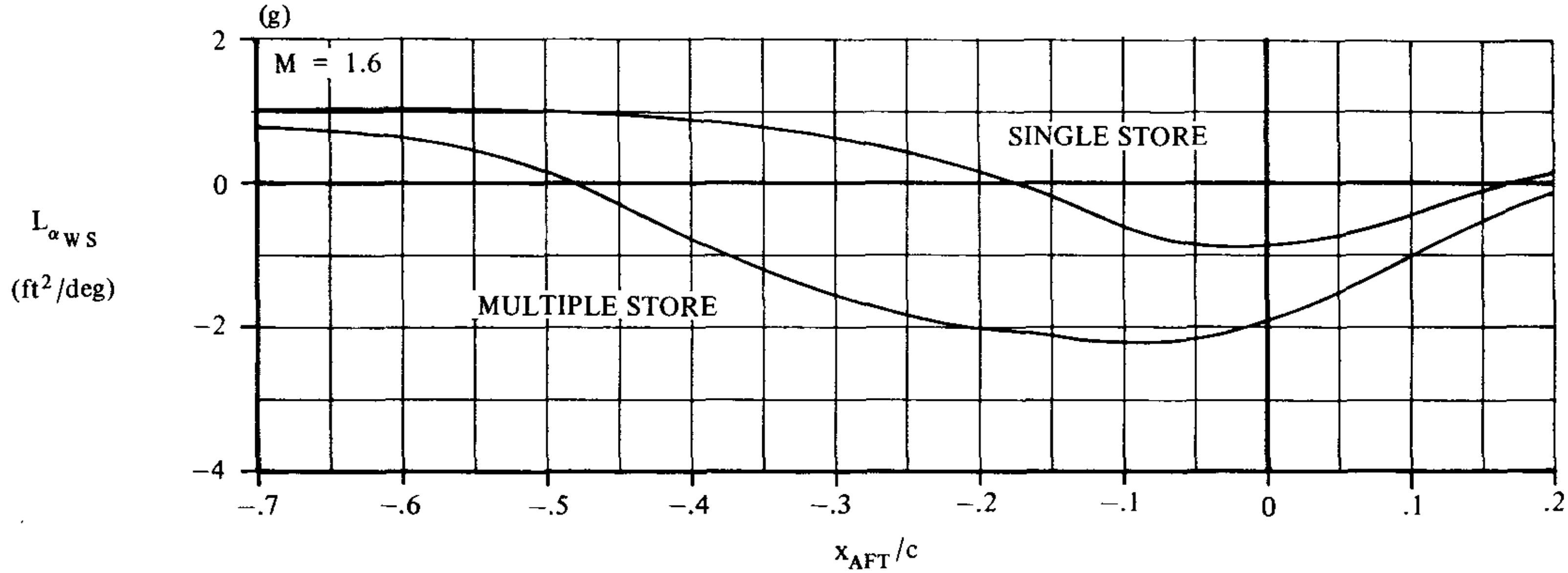


FIGURE 3.1.1-21 (CONTD)



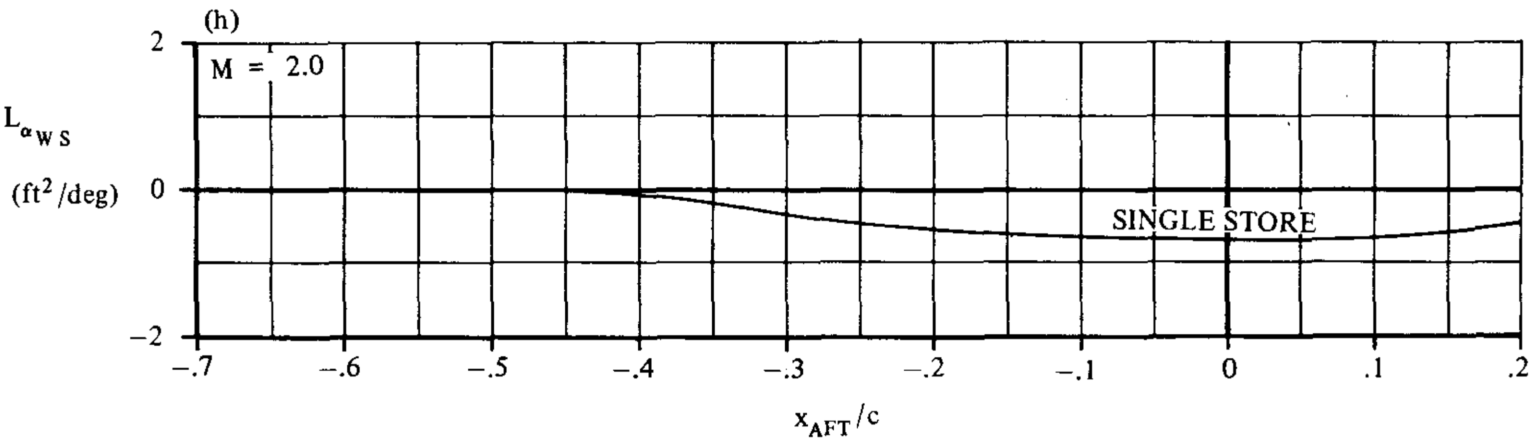


FIGURE 3.1.1-21 (CONTD)

3.1.2 LIFT INCREMENT DUE TO FUSELAGE-MOUNTED STORE INSTALLATIONS

A method is presented in this section for estimating the aircraft lift-coefficient increment due to fuselage-mounted store installations. The method as presented is for estimating the increment due to a pair of symmetric fuselage-mounted installations. The increment due to a single installation may also be obtained by using half the increment due to the pair of symmetric installations.

The Datcom Method is taken from Reference 1 and is empirical in nature. The method is applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberance. The limitations on configuration and Mach-number range are summarized in Table 3.1-A. Additional limitations and assumptions pertaining to the method are listed below:

1. The method has not been validated for pylon heights greater than 10 inches.

2. The method is limited to store installations which are not mounted beyond 90 percent of the fuselage semispan from the fuselage centerline.

3. The method has been verified for a Mach-number range between M = 0.6 and M = 2.0 with a few exceptions. Caution should be used in extrapolating the empirical curves beyond the given Mach-number range.

4. The method has not been verified for configurations in which flaps, slats or other flow-disrupting devices are deployed.

5. The method gives the best results for an angle-of-attack range from 0 to 8°, although the method can be used for higher angles of attack.

6. The data base used in deriving the method relied heavily on swept-wing tactical-combat-aircraft wind-tunnel data.

7. No method is provided to estimate fuselage and adjacent-store interference effects. These effects may be significant if the separation distances are less than 3 store diameters. Proximity to engine inlets may also be significant.

8. The method is applicable for sideslip angles less than 4°.

The loading configuration capabilities of the method are given in Table 3.1.2-A. Each configuration is assigned a number which is referred to throughout the method. The method is applied separately to each single store installation or symmetrical pair of store installations.

TABLE 3.1.2-A

STORE CONFIGURATION SUMMARY

Store Configuration			Configuration Number
Mounting	Carriage	Loading	
Pylon	None	Empty	1
	Single	Single	1
Tangent	Single	Single	1
Pylon	MER	Empty	2
		Partially Loaded	2
		Full	2
Tangent		Empty	2
		Partially Loaded	2
		Full	2
Pylon	TER	Empty	3
		Partially Loaded	3
		Full	3
Tangent		Empty	3
		Partially Loaded	3
		Full	3

A. SUBSONIC

DATCOM METHOD

The incremental lift coefficient, based on wing reference area, due to a pair of symmetric fuselage-mounted external-store installations is given by Equation 3.1.2-a. (For a single installation, this value should be divided by two.)

$$\Delta C_{L_{FS}} = \frac{1}{S_W}\left[L_R K_{WING} K_{SPAN} + L_{\alpha_{FS}}(\alpha - 4.0)\right] \qquad 3.1.2\text{-a}$$

where

S_W is the wing reference area (ft^2).

L_R is an incremental-lift effect due to carriage-rack installation obtained from Figures 3.1.1-12 through 3.1.1-14 of Section 3.1.1 as a function of Mach number and S_{W_a}. (Refer to the discussion presented in Section 3.1.1 in relation to the Mach-number range and configuration applicability of this parameter.)

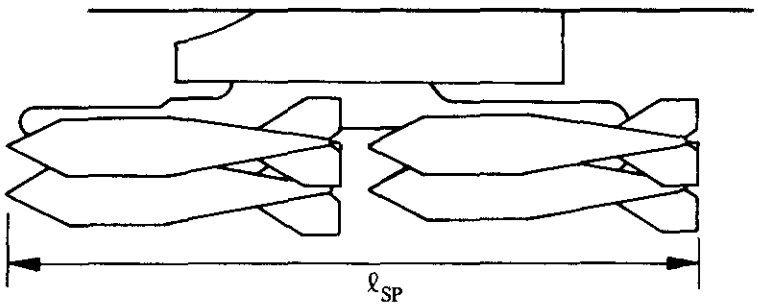
where, for fuselage-mounted installations

S_{W_a} is the pseudo store installation planform area ($in.^2$) for both installations, and is given by

$$S_{W_a} = 2\ell_{SP} d_w \qquad 3.1.2\text{-b}$$

where

ℓ_{SP} is the maximum store/pylon installation length (in.). (See Sketch (a).)



SKETCH (a)

d_w is the maximum width (in.) of the store installation not including protruding fins and is given by

1. For an empty pylon:

$$d_w = 1.5 \times \text{(maximum pylon width)} \qquad 3.1.2\text{-c}$$

2. For a single store:

$$d_w = d_S \qquad 3.1.2\text{-d}$$

(d_S is the maximum store diameter)

K_{WING} is a parameter to account for the effect of wing location on the fuselage. This parameter is obtained from Figure 3.1.2-6 as a function of z_w/h_f where

z_w is the distance from the top of the fuselage to the midpoint of the wing intersection with the fuselage (including canopy protuberances) (See Figure 3.1.2-6).

h_f is the overall height of the fuselage (including canopy protuberances) (See Figure 3.1.2-6).

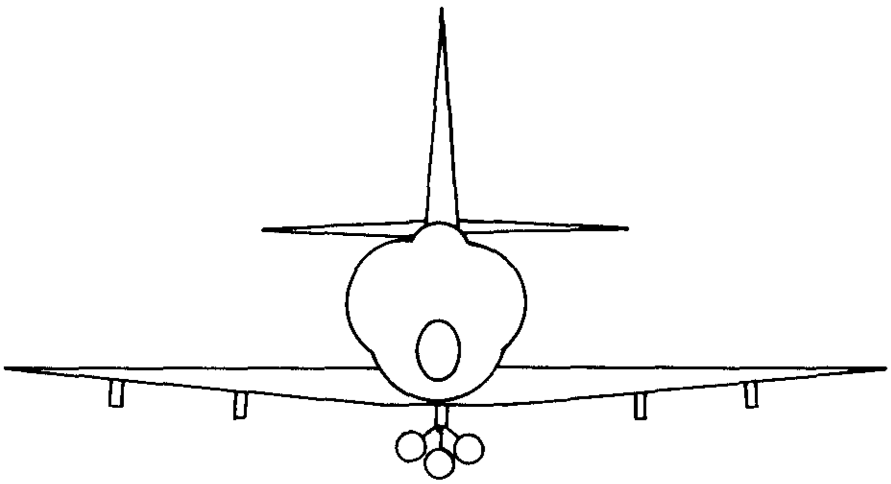
K_{SPAN} is a parameter to account for the effect of lateral placement of the store installation. The parameter is obtained from Figure 3.1.2-7 and is available for store installations mounted within 90% of the fuselage semispan from the fuselage centerline.

$L_{\alpha_{FS}}$ is an effect due to aircraft angle of attack obtained from Figure 3.1.2-8 as a function of aircraft wing location and Mach number.

α is the aircraft angle of attack (deg).

Sample Problem

Given: A swept-wing subsonic fighter aircraft (Reference 2) loaded with a pylon-mounted MER containing five 500-lb. bombs (two of the bombs are hidden in the front view) located below the fuselage centerline.



FRONT VIEW

Aircraft Data:

$S_W = 260\ ft^2$ $\qquad$ $z_w/h_f = 0.88$

Stores Data:

$d_S = 12$ in.

Installation Data:

$d_w = 33.6$ in. $\qquad$ $h_p = 11.2$ in. $\qquad$ $\ell_{SP} = 185.6$ in.

Additional Data:

$M = 0.8$ $\qquad$ $\alpha = 8^o$

It is noted from Table 3.1.2-A that this is Configuration Number 2. Since the loading is not a symmetrical pair of installations, the final result will be divided by 2 to obtain the increment for a single installation.

Compute:

$S_{W_a} = 2\ell_{SP} d_w$ (Equation 3.1.2-b)

$= (2)(185.6)(33.6)$

$= 12{,}472 \text{ in.}^2$

L_R	$= -17.0$	(Figure 3.1.1-13, Configuration 2)
z_w/h_f	$= 0.88$	(Given)
K_{WING}	$= 0.93$	(Figure 3.1.2-6)
K_{SPAN}	$= 1.0$	(Figure 3.1.2- 7)
$L_{\alpha_{FS}}$	$= 0.15$	(Figure 3.1.2- 8)

Solution:

$$\Delta C_{L_{FS}} = \frac{1}{S_W}\left[L_R K_{WING} K_{SPAN} + L_{\alpha_{FS}}(\alpha - 4.0)\right] \qquad \text{(Equation 3.1.2-a)}$$

$$= \frac{1}{260}[(-17.0)(0.93)(1.0) + (0.15)(8.0 - 4.0)]$$

$$= -0.0585 \quad \text{(symmetrical pair)}$$

For a single installation,

$$\Delta C_L = \frac{\Delta C_{L_{FS}}}{2} = \frac{-0.0585}{2} = -0.02925$$

The calculated value of $\Delta C_{L_{FS}}$ is combined with wing-store increments in the Sample Problem of Section 3.1.3 to illustrate a complex loading configuration. Comparison of the calculated results with test data is provided in that section.

B. TRANSONIC

The method presented in Paragraph A of this section is also valid for transonic speeds. The user is cautioned that the accuracy of the method is less than that expected in the subsonic speed range; and test data should be used whenever possible.

C. SUPERSONIC

The method presented in Paragraph A of this section is also valid for supersonic speeds. The expected accuracy of the method is comparable to that in the subsonic range. The maximum Mach number provided in the design figures indicates the level to which the method is substantiated. Caution should be used when extrapolating the data beyond the Mach range provided in the figures.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer. McDonnell Douglas Corporation Rept. DAC-67425, 1968. (U)

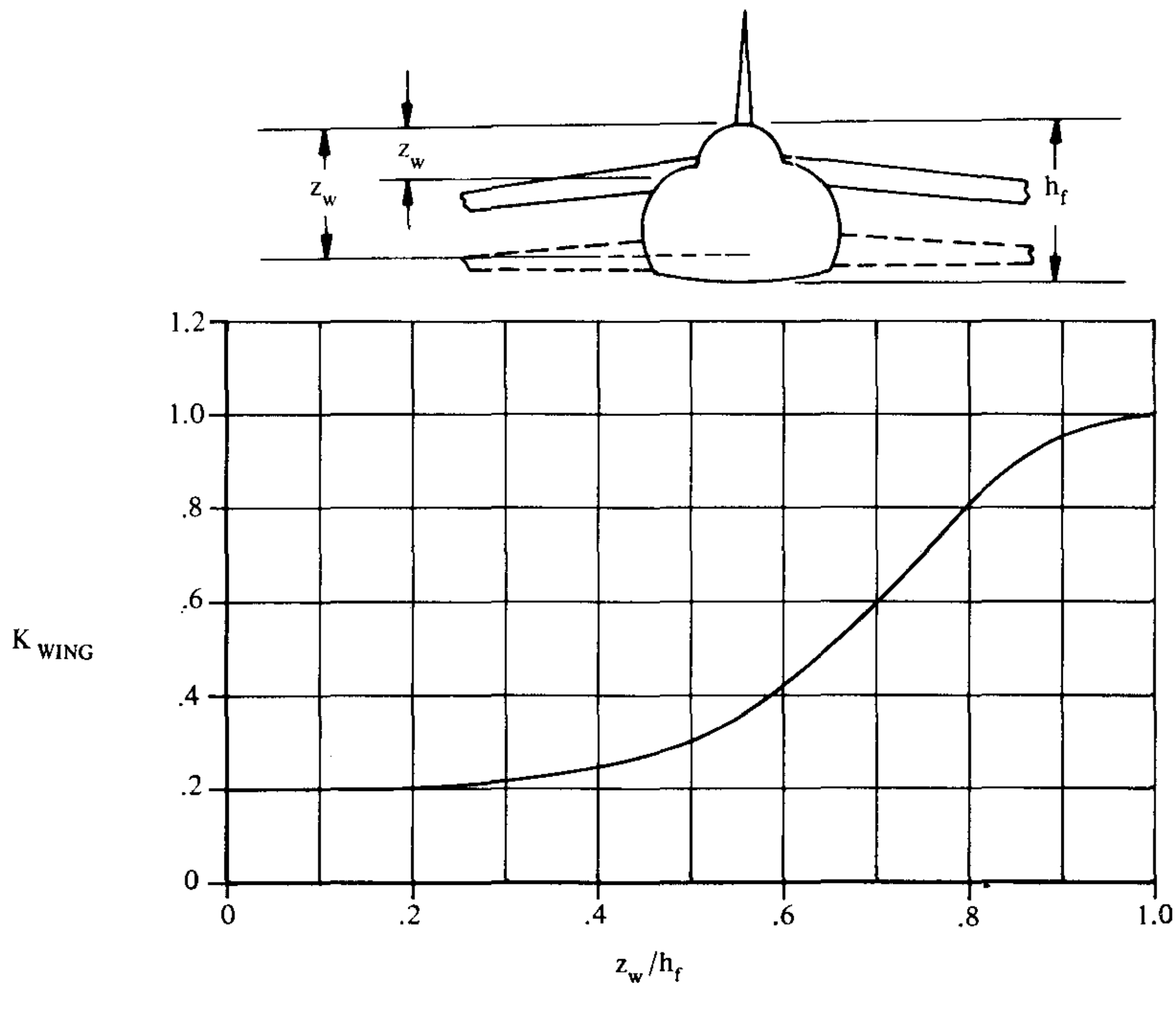


FIGURE 3.1.2-6 WING-LOCATION PARAMETER

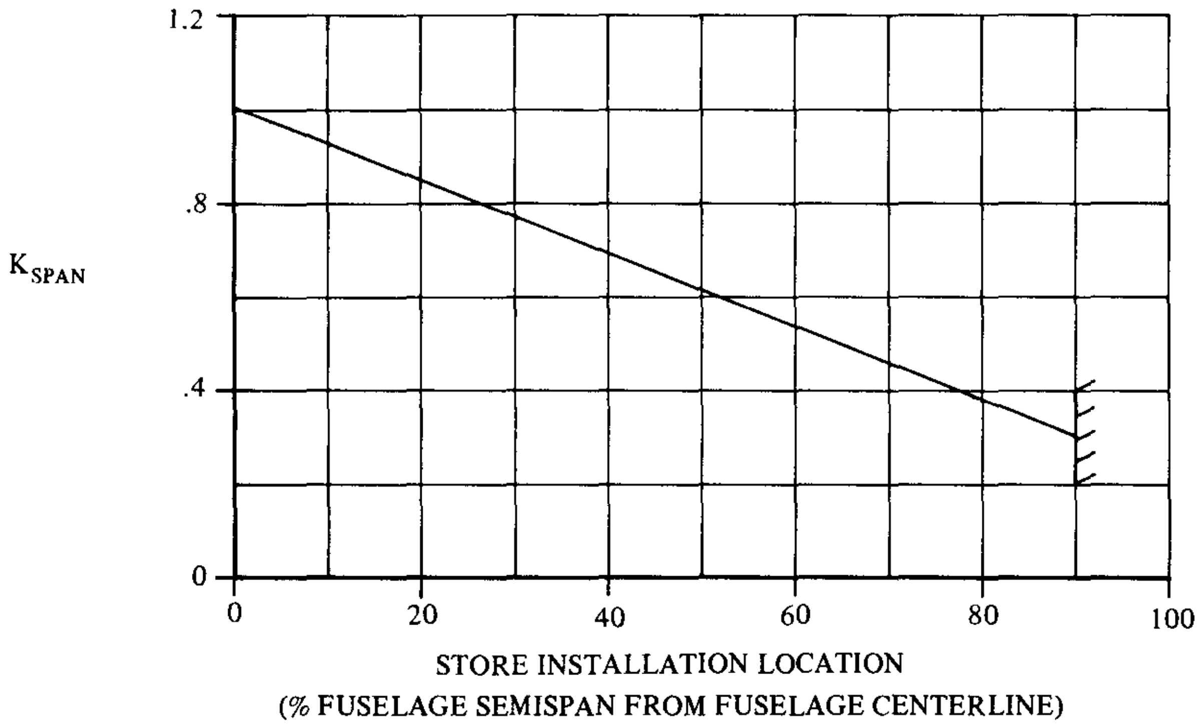


FIGURE 3.1.2- 7 LATERAL-PLACEMENT FACTOR FOR FUSELAGE-MOUNTED STORES

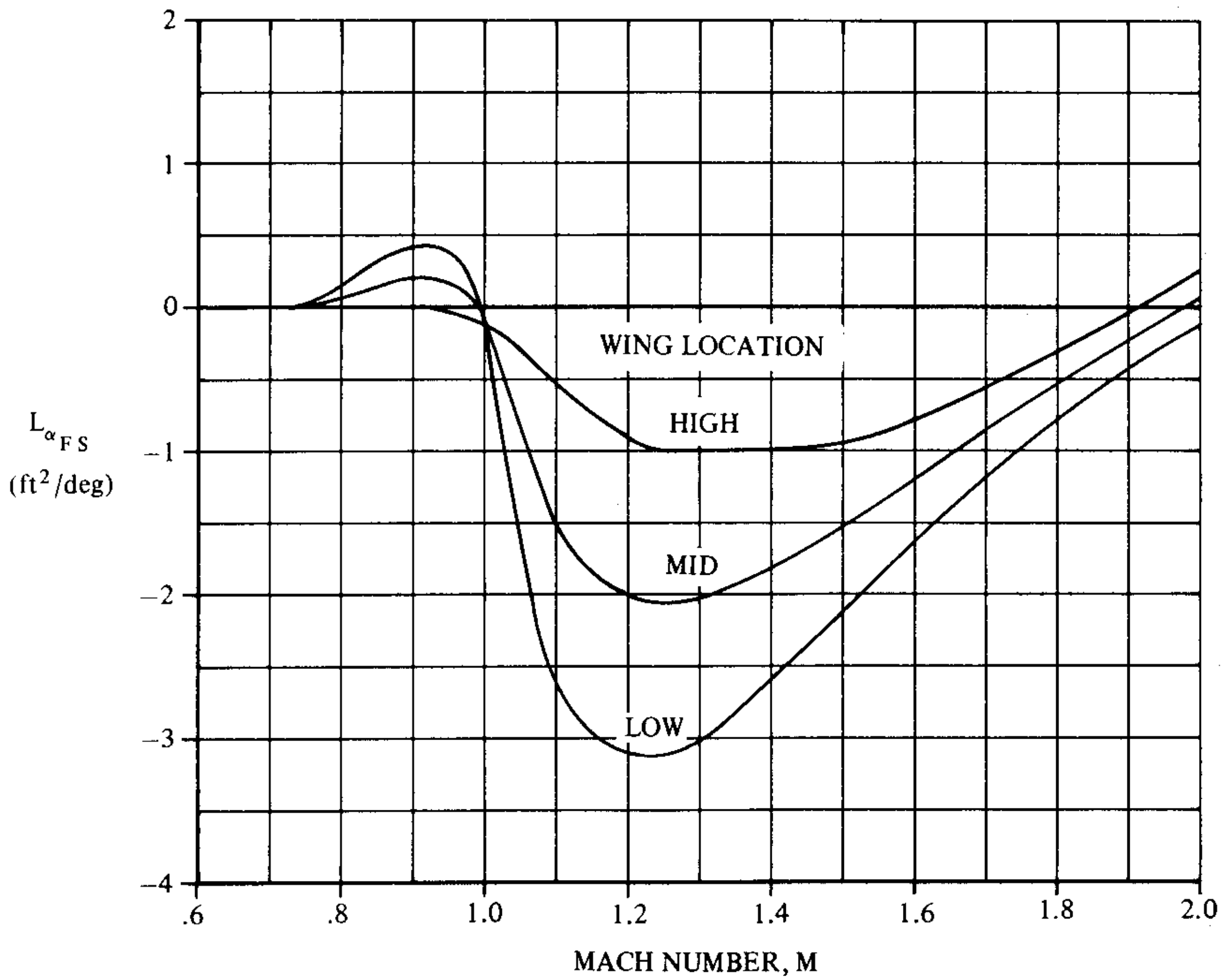


FIGURE 3.1.2- 8 FUSELAGE-STORES INCREMENTAL-LIFT EFFECT DUE TO ANGLE OF ATTACK

3.1.3 TOTAL AIRCRAFT LIFT INCREMENT DUE TO EXTERNAL STORES

A method is presented in this section for estimating the total aircraft lift-coefficient increment due to external-store installations. The method predicts the increments for symmetric, asymmetric, and multiple-installation loading configurations.

The Datcom method is taken from Reference 1 and is empirical in nature. The method is applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The limitations on configuration and Mach-number range are summarized in Table 3.1-A. Additional limitations and assumptions pertaining to the method are listed below:

1. The method is not applicable to wing-tip or wing-tangent-mounted stores.

2. The method has not been validated for fuselage installations with pylon heights greater than 10 inches.

3. The method for fuselage-mounted stores is limited to installations which are not mounted beyond 90 percent of the fuselage semispan from the fuselage centerline.

4. The method has been verified for a Mach-number range between $M = 0.6$ and $M = 2.0$ with a few exceptions. Caution should be used in extrapolating the empirical curves beyond the given Mach-number range.

5. The method has not been verified for configurations in which flaps, slats or other flow-disrupting devices are deployed.

6. The method gives the best results for an angle-of-attack range from 0 to 8°, although the method can be used for higher angles of attack.

7. The data base used in deriving the method relied heavily on swept-wing tactical-combat-aircraft wind-tunnel data.

8. No method is provided to estimate fuselage and adjacent-store interference effects. These effects may be significant if the separation distances are less than 3 store diameters. Proximity to engine inlets may also be significant.

9. The method is applicable for sideslip angles less than 4°.

The procedure for computing the total lift-coefficient increment requires calculation of the increments for wing and fuselage installations separately by the methods of Sections 3.1.1 and 3.1.2, respectively. The increments for each installation are then summed to obtain the total increment.

A. SUBSONIC

DATCOM METHOD

The total aircraft lift-coefficient increment due to external-store installations and based on wing reference area, S_W, is given by

$$\Delta C_L = \sum_{i=0}^{N_{S_i}} (\Delta C_L)_i + \sum_{j=0}^{N_{A_j}} (\Delta C_L)_j \qquad 3.1.3\text{-a}$$

where

N_{S_i} is the total number of pairs of symmetrical external-store installations.

$(\Delta C_L)_i$ is the incremental lift coefficient due to a pair of symmetrical store installations where:

For wing-mounted installations

$$(\Delta C_L)_i = \Delta C_{L_{WS}} \qquad 3.1.3\text{-b}$$

and $\Delta C_{L_{WS}}$ is calculated in Section 3.1.1.

For fuselage-mounted installations

$$(\Delta C_L)_i = \Delta C_{L_{FS}} \qquad 3.1.3\text{-c}$$

and $\Delta C_{L_{FS}}$ is calculated in Section 3.1.2.

N_{A_i} is the total number of asymmetrical external-store installations.

$(\Delta C_L)_j$ is the incremental lift coefficient due to an asymmetric store installation where:

For wing-mounted installations,

$$(\Delta C_L)_j = \frac{1}{2} \Delta C_{L_{WS}} \qquad 3.1.3\text{-d}$$

and $\Delta C_{L_{WS}}$ is calculated in Section 3.1.1.

For fuselage-mounted installations

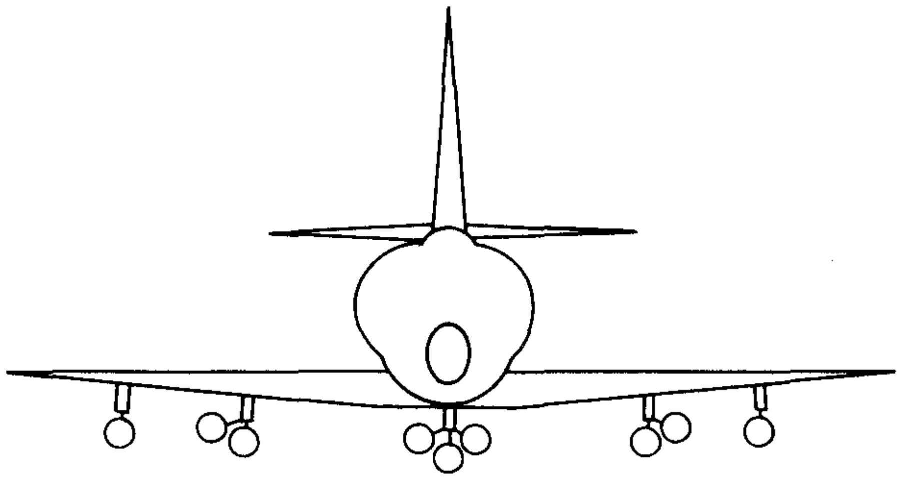
$$(\Delta C_L)_j = \frac{1}{2} \Delta C_{L_{FS}} \qquad 3.1.3\text{-e}$$

and $\Delta C_{L_{FS}}$ is calculated in Section 3.1.2.

Reference 1 states that prediction errors for incremental lift are nominally 20 percent. This generally results in an overall accuracy within 2 percent of total aircraft lift. Comparisons of test and calculated results are presented in Reference 1.

Sample Problem

Given: A swept-wing subsonic fighter aircraft from Reference 2, loaded as follows: (This is a combination of the configuration of the Sample Problems from Sections 3.1.1 and 3.1.2.)



FRONT VIEW

Spanwise Station	Rack Type	Mounting	Store Type	No. of Stores	Configuration Number
Centerline	MER	Pylon	500-lb Bomb	5	2
Inboard Wing	TER	Pylon	500-lb Bomb	2	3
Outboard Wing	Single	Pylon	500-lb Bomb	1	1

Additional Characteristics:

$M = 0.8$ $\qquad\qquad \alpha = 8^{\circ}$

(Additional geometric data are provided in the Sample Problems of Sections 3.1.1 and 3.1.2.)

Compute:

$N_{S_i} = 2$ (inboard- and outboard-wing installations)

$N_{A_i} = 1$ (centerline installation)

$(\Delta C_L)_i$ for $i = 1,2$:

$(\Delta C_L)_1 = \Delta C_{L_{WS}}$ $\qquad$ (Equation 3.1.3-b) where $\Delta C_{L_{WS}}$ is evaluated at the outboard-wing station and computed in the Sample Problem of Section 3.1.1.

$$(\Delta C_L) = \Delta C_{L_{WS}} = 0.00312$$

$$(\Delta C_L)_2 = \Delta C_{L_{WS}} \qquad \text{(Equation 3.1.3-b)}$$

where $\Delta C_{L_{WS}}$ is evaluated at the inboard-wing station and computed in the Sample Problem of Section 3.1.1.

$$(\Delta C_L)_2 = \Delta C_{L_{WS}} = -0.0107$$

$(\Delta C_L)_j$ for $j = 1$:

$$(\Delta C_L)_1 = \frac{1}{2}\Delta C_{L_{FS}} \qquad \text{(Equation 3.1.3-e)}$$

where $\Delta C_{L_{FS}}$ is evaluated at the fuselage-centerline station and computed in the Sample Problem of Section 3.1.2.

$$(\Delta C_L)_1 = \Delta C_{L_{FS}} = -0.02925$$

Solution:

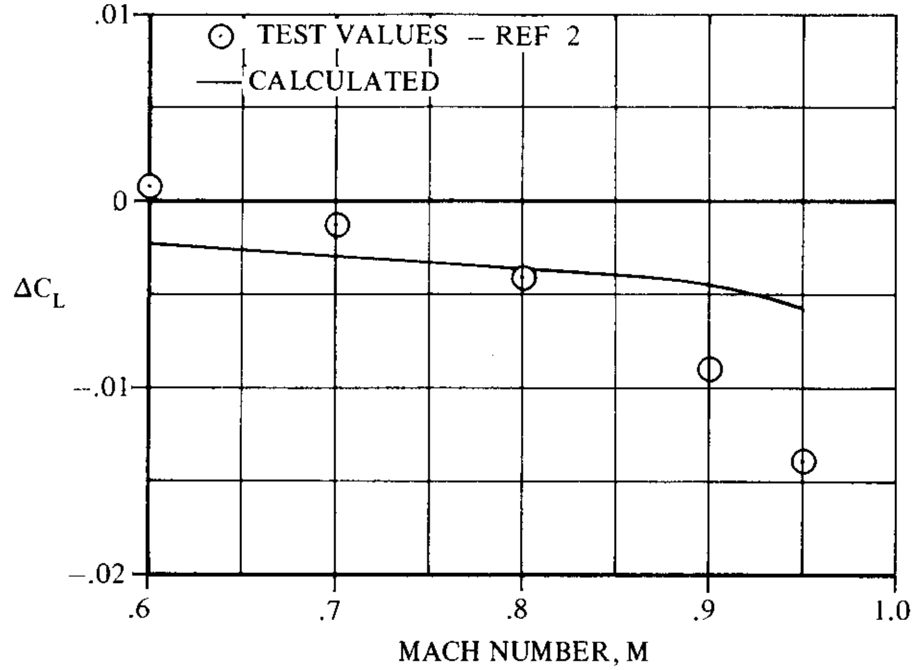
$$\Delta C_L = \sum_{i=0}^{N_{S_i}} (\Delta C_L)_i + \sum_{j=0}^{N_{A_i}} (\Delta C_L)_j \qquad \text{(Equation 3.1.3-a)}$$

$$\Delta C_L = \sum_{i=0}^{2} (\Delta C_L)_i + \sum_{j=0}^{1} (\Delta C_L)_j$$

$$= 0.00312 - 0.0107 - 0.02925$$

$$= -0.0368$$

Calculated results at additional Mach numbers are shown in comparison to test data from Reference 2 in Sketch (a).



SKETCH (a)

B. TRANSONIC

The method presented in Paragraph A of this section is also valid for transonic speeds. The user is cautioned that the accuracy of the method is less than that expected in the subsonic speed range.

C. SUPERSONIC

The method presented in Paragraph A of this section is also valid for the supersonic speed range. The maximum Mach number provided in the design figures indicates the level to which the method is substantiated.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer. McDonnell Douglas Corporation Report DAC-67425, 1968. (U)

3.2 EFFECT OF EXTERNAL STORES ON AIRCRAFT DRAG

Methods are presented in this section for estimating the change in aircraft drag due to external-store installations. The methods predict an incremental change in drag coefficient, based on wing reference area, which can be added to the clean-aircraft drag coefficient to obtain the aircraft-with-stores drag coefficient. These methods are taken from Reference 1 and are empirical in nature.

Section 3.2 is subdivided as follows:

The total drag increment is the sum of the incremental drag at zero lift and the incremental drag due to lift. These components are computed in terms of equivalent-parasite-drag area for each installation by the methods of Sections 3.2.1 and 3.2.2 and are combined to obtain the total-drag-coefficient increment by the method of Section 3.2.3.

The Datcom methods are applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The methods are limited to the store-loading configurations and Mach-number ranges presented in Table 3.2-A. The methods are applicable to mixed loading configurations obtained by combining two or more loadings specified in Table 3.2-A. Additional limitations are specifically noted in each of the sections that follow.

TABLE 3.2-A

LOADING AND MACH-NUMBER LIMITATIONS

Mounting Location	Carriage Mode	Mount/Loading Type	Mach-Number Range
Wing	Single	Pylon – Empty	0.6 → 2.0
		Pylon – Single Store	
	Multiple	Pylon – Empty MER	0.6 → 1.6
		Pylon – Fully Loaded MER	
		Pylon – Partially Loaded MER	
		Pylon – Empty TER	
		Pylon – Fully Loaded TER	
		Pylon – Partially Loaded TER	
Fuselage	Single	Tangent – One Store	0.6 → 1.6
		Tangent – Two or More Stores	0.6 → 0.9
		Pylon – Empty	0.6 → 2.0
		Pylon – One Store	0.6 → 1.6
		Pylon – Two or More Stores	0.6 → 0.9
	Multiple	Tangent – One Store Installation	0.6 → 1.6
		Pylon – One Store Installation	
Wing or Fuselage		Adjacent Store Installation Interference	0.6 → 1.2
		Additional Drag Due to Lift	0.6 → 1.6

REFERENCE

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

3.2.1 DRAG AT ZERO LIFT

3.2.1.1 BASIC DRAG DUE TO STORE INSTALLATIONS

Methods are presented in this section for estimating the zero-lift equivalent-parasite-drag area due to a store installation. This drag component does not include adjacent-store and fuselage interference effects (see Sections 3.2.1.2 and 3.2.1.3). The Datcom methods are presented for a particular store installation type and loading configuration, and are applied separately to each installation (armament station).

The methods are taken from Reference 1 and are empirical in nature. The methods are applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The limitations on configuration and Mach-number range are summarized in Table 3.2-A. Additional limitations and assumptions pertaining to the methods are listed below; however, some additional limitations pertaining to a specific method are given in the method descriptions.

1. The empirical design curves used in the methods generally do not provide data below $M = 0.6$, although the methods have been verified for some cases below this speed. Caution should be used when extrapolating the curves beyond the given Mach range.

2. The methods are not applicable to wing-tip and wing-tangent-mounted stores.

3. The methods have not been verified for configurations in which flaps, slats, or other flow-disrupting devices are deployed.

4. The angle-of-attack range is from zero to cruise angle of attack.

5. The data base used in deriving the methods relied heavily on swept-wing tactical-combat-aircraft wind-tunnel data.

6. The methods are applicable for sideslip angles less than 4°.

Methods are presented for the following particular store installation type and loading configurations:

Wing-Mounted Empty Pylon
Wing-Pylon-Mounted Single Store
Wing-Pylon-Mounted Empty MER
Wing-Pylon-Mounted Fully Loaded MER
Wing-Pylon-Mounted Partially Loaded MER
Wing-Pylon-Mounted Empty TER
Wing-Pylon-Mounted Fully Loaded TER
Wing-Pylon-Mounted Partially Loaded TER
Fuselage-Tangent-Mounted Stores (Two or More Single Stores)
Fuselage-Mounted Empty Pylon
Fuselage-Pylon-Mounted Stores (Two or More Single Stores)
Fuselage-Tangent-Mounted Single Store (One Installation)
Fuselage-Tangent-Mounted MER (One Installation)
Fuselage-Pylon-Mounted Single Store (One Installation)
Fuselage-Pylon-Mounted MER (One Installation)

A. SUBSONIC

DATCOM METHODS

The Datcom user should proceed directly to the method appropriate to the particular store installation type and loading configuration of interest.

Wing-Mounted Empty Pylon

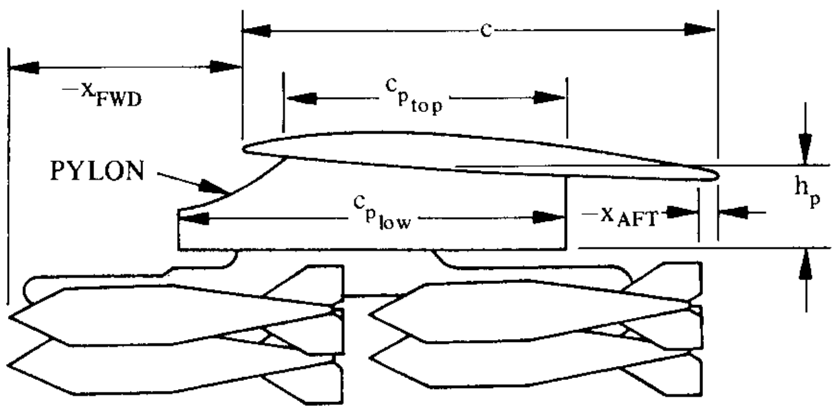
The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by

$$D_B = \left(B_{xx} + K_{xx}\frac{S_P}{144}\right)\left[K_{CJK}\frac{t_{p_{max}}}{0.04}\left(\frac{2}{c_{p_{top}} + c_{p_{low}}}\right)(0.35 + 0.2167R_U)\right] + D_{PR} \qquad 3.2.1.1\text{-a}$$

where

B_{xx} is an empty-pylon drag factor obtained from Figure 3.2.1.1-20 as a function of Mach number and S_P, the pylon frontal area obtained by measuring the maximum cross-sectional area of the isolated pylon.

K_{xx} is an empty-pylon correlation ratio obtained from Figure 3.2.1.1-21a as a function of Mach number and x_{AFT}/c. The value of x_{AFT} is the longitudinal distance (in.) from the local wing trailing edge to the trailing edge of the store installation (or pylon trailing edge for the empty-pylon case), positive in the aft direction. (See Sketch (a).) The value of c is the local wing chord (in.) at the particular store or pylon station. (See Sketch (a).)



SKETCH (a)

K_{CJK} is a pylon Mach-number correlation parameter obtained from Figure 3.2.1.1-21b as a function of Mach number.

$t_{p_{max}}$ is the maximum pylon thickness (in.).

$c_{p_{top}}$ is the pylon-top-chord length (in.) at the wing-pylon juncture. (See Sketch (a).)

$c_{p_{low}}$ is the pylon-bottom chord length (in.). (See Sketch (a).)

R_U is a pylon-underside-roughness factor given by

$$\left.\begin{array}{l} R_U = 3, \text{ for the pylon-underside case (typical of wind-tunnel model) or for loaded pylons.} \\ R_U = 4, \text{ for a rough-pylon-underside case (typical of full-scale hardware).} \\ R_U = 5, \text{ for an extremely rough-pylon-underside case, i.e., containing large cavities.} \end{array}\right\} \quad 3.2.1.1\text{-b}$$

D_{PR} is the pylon-rack equivalent-parasite-drag area (ft^2) given by Figure 3.2.1.1.-22a as a function of Mach number.

Wing-Pylon-Mounted Single Store

The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by separate equations at discrete Mach numbers. To obtain values at intermediate Mach numbers, interpolation must be used.

For M = 0.6:

$$D_B = B + \delta \qquad 3.2.1.1\text{-c}$$

where

B is the equivalent-parasite-drag area (ft^2) computed at M = 0.90 and given by

$$B = D_{ILP} + D_{IS} + D_I \qquad 3.2.1.1\text{-d}$$

where

D_{ILP} is the equivalent-parasite-drag area (ft^2) of the installed loaded pylon given by D_B in Equation 3.2.1.1-a evaluated at M = 0.90 and R_U = 3.

D_{IS} is the isolated-store equivalent-parasite-drag area (ft^2) at M = 0.90, given by

$$D_{IS} = S_\pi C_{D_\pi} \qquad 3.2.1.1\text{-e}$$

where

S_π is the store maximum cross-sectional area (ft^2).

C_{D_π} is the isolated-store drag coefficient at zero lift based on store maximum cross-sectional area. This term can be provided by the user, or can be estimated by using Section 4.2.3.1.

D_I is the equivalent-parasite-drag area (ft^2) due to pylon-store-aircraft interference at M = 0.90, given by

$$D_I = D_X + U_{\bar{y}} V_{\bar{x}} + E_u (22.6 - h_p) \qquad 3.2.1.1\text{-f}$$

where

D_X is the equivalent-parasite-drag area (ft^2) due to store-to-aircraft interference given by Figure 3.2.1.1-22b as a function of x_{AFT}/c, where x_{AFT} and c were previously defined for the wing-mounted empty-pylon case.

$U_{\bar{y}}$ is a lateral drag interference factor (ft) obtained from Figure 3.2.1.1-23a as a function of $\bar{y}$, the fraction of wing semispan location of the store station measured from the aircraft centerline.

$V_{\bar{x}}$ is a longitudinal drag interference factor (ft) obtained from Figure 3.2.1.1-23b as a function of x_{AFT}/c.

E_u is a pylon-height interference factor (ft^2/in.) obtained from Figure 3.2.1.1-23c as a function of x_{AFT}/c.

h_p is the average pylon height (in.). (See Sketch (a).)

δ is the equivalent-parasite-drag area (ft^2) obtained from Figure 3.2.1.1-24 as a function of B.

For M = 0.8:

$$D_B = B + 0.8\delta \qquad 3.2.1.1\text{-g}$$

where B and δ were defined previously.

For M = 0.9:

$$D_B = B \qquad 3.2.1.1\text{-h}$$

where B is given by Equation 3.2.1.1-d.

For M > 0.9, see Paragraphs B and C of this section.

Wing-Pylon-Mounted Empty MER

The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by

$$D_B = D_{ILP} + D_{MSB} + D_{IMR} \qquad 3.2.1.1\text{-i}$$

where

D_{ILP} is defined in the Wing-Pylon-Mounted Single-Store Case.

D_{MSB} is the MER sway-brace equivalent-parasite-drag area (ft^2) obtained from Figure 3.2.1.1-25 as a function of Mach number.

D_{IMR} is the installed-MER equivalent-parasite-drag area (ft^2) given by

$$D_{IMR} = R_{F_M} + R_{A_M} \qquad 3.2.1.1\text{-j}$$

where

R_{F_M} is a MER forward-longitudinal-placement term (ft^2) obtained from Figure 3.2.1.1-26 as a function of x_{FWD}/c and Mach number, where x_{FWD} is the distance from the local wing leading edge to the store/pylon nose (in.), positive for store nose aft of the local wing leading edge. (See Sketch (a).) The value of c is the local wing chord (in.) at the particular store or pylon station. (See Sketch (a).)

R_{A_M} is a MER aft-longitudinal-placement term (ft^2) obtained from Figure 3.2.1.1-27 as a function of x_{AFT}/c and Mach number, where x_{AFT} was previously defined for a Wing-Mounted Empty-Pylon Case. (See Sketch (a).)

Wing-Pylon-Mounted Fully Loaded MER

The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by

$$D_B = D_{EM} + 6D_{IS} + D_{IM} \qquad 3.2.1.1\text{-k}$$

where

D_{EM} is the empty-MER equivalent-parasite-drag area (ft^2) given by D_B from Equation 3.2.1.1-i.

D_{IS} is the isolated-store equivalent-parasite-drag area at $M = 0.9$. (See Equation 3.2.1.1-e.)

D_{IM} is the equivalent-parasite-drag area (ft^2) due to store-MER-aircraft interference, given by

$$D_{IM} = M_{I_S}\left(\frac{z_e^2\, d_w}{144c} - 30\right) + M_{I_I} \qquad 3.2.1.1\text{-}\ell$$

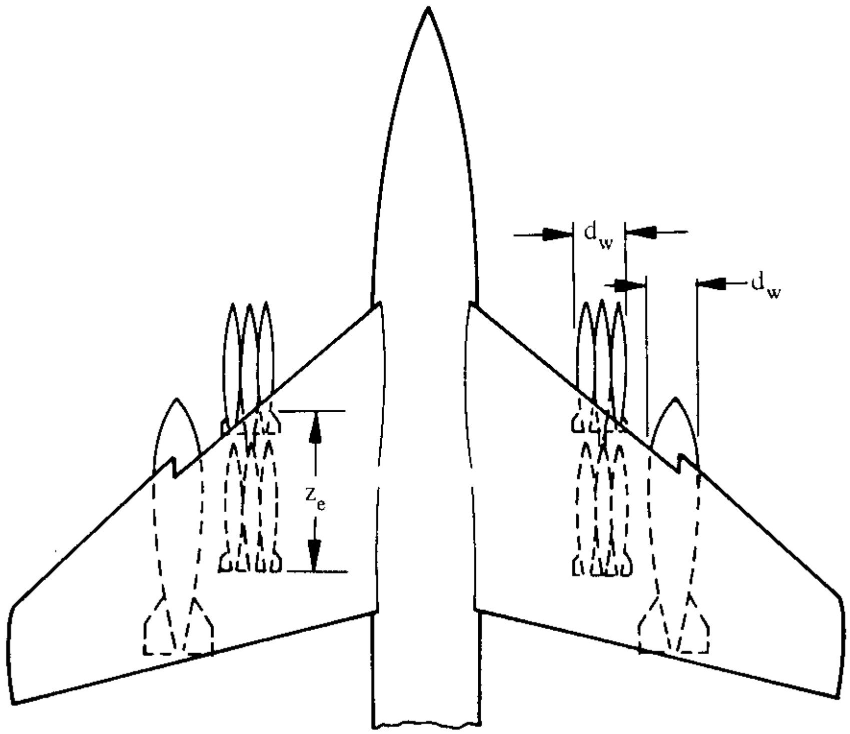
where

M_{I_S} is a store-MER-aircraft-interference Mach-correlation factor obtained from Figure 3.2.1.1-28 as a function of Mach number.

z_e is the vertically projected length of the store installation on the aircraft wing (in.). (See Sketch (b).)

d_w is the maximum width of the store installation (in.) not including protruding fins. (See Sketch (b).)

c is the local wing chord (in.) at the particular store or pylon station. (See Sketch (a).)



SKETCH (b)

M_{I_I} is a MER adjacent-store separation factor (ft^2) obtained from Figure 3.2.1.1-29 as a function of Mach number and d_c/d_S, where

d_c is the minimum clearance between adjacent stores. (See Figure 3.2.1.1-29.)

d_S is the maximum store diameter.

Wing-Pylon-Mounted Partially Loaded MER

The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by

$$D_B = D_{EM}\left(1 - \frac{N_{S_M} T_F}{6}\right) + D_{FLM} \qquad 3.2.1.1\text{-m}$$

where

D_{EM} was defined in the Wing-Pylon-Mounted Fully Loaded MER Case.

N_{S_M} is the total number of stores attached to the MER.

T_F is the tandem-stores factor given by

$$\left.\begin{aligned} T_F &= 1.00 \text{ for } N_{S_M} = 1, 5 \text{ or } 6 \text{ stores} \\ &= 1.00 \text{ for } N_{S_M} = 4 \text{ stores total with one store in tandem} \\ &= 0.90 \text{ for } N_{S_M} = 4 \text{ stores total with two stores in tandem} \\ &= 1.0 \text{ for } N_{S_M} = 3 \text{ stores total with one store in tandem} \\ &= 1.10 \text{ for } N_{S_M} = 3 \text{ stores total with none in tandem} \\ &= 0.90 \text{ for } N_{S_M} = 2 \text{ stores total with one store in tandem} \\ &= 1.10 \text{ for } N_{S_M} = 2 \text{ stores total with none in tandem} \end{aligned}\right\} \qquad 3.2.1.1\text{-n}$$

D_{FLM} is the zero-lift equivalent-parasite-drag area (ft^2) due to a fully loaded MER given by D_B in Equation 3.2.1.1-k.

Wing-Pylon-Mounted Empty TER

The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by

$$D_B = D_{ILP} + D_{TSB} + D_{ITR} \qquad 3.2.1.1\text{-o}$$

where

D_{ILP} is defined in the Wing-Pylon-Mounted Single-Store Case.

D_{TSB} is the TER sway-brace equivalent-parasite-drag area (ft^2) obtained from Figure 3.2.1.1-30 as a function of Mach number.

D_{ITR} is the installed-TER equivalent-parasite-drag area (ft^2) given by

$$D_{ITR} = R_{F_T} + R_{A_T} \qquad 3.2.1.1\text{-p}$$

where

R_{F_T} is a TER forward-longitudinal-placement term (ft^2) obtained from Figure 3.2.1.1-31 as a function of x_{FWD}/c and Mach number, where x_{FWD} and c was previously defined for a Wing-Pylon-Mounted Empty-MER Case.

R_{A_T} is a TER aft-longitudinal-placement term (ft^2) obtained from Figure 3.2.1.1-32 (ft^2) as a function of x_{AFT}/c and Mach number, where x_{AFT} was previously defined for a Wing-Mounted Empty-Pylon Case.

Wing-Pylon-Mounted Fully Loaded TER

The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by

$$D_B = D_{ET} + 3D_{IS} + D_{IT} \qquad 3.2.1.1\text{-q}$$

where

D_{ET} is the empty-TER equivalent-parasite-drag area (ft^2) given by D_B from Equation 3.2.1.1-o.

D_{IS} is the isolated-store equivalent-parasite-drag area (ft^2) at $M = 0.9$, given by Equation 3.2.1.1-e.

D_{IT} is the equivalent-parasite-drag area (ft^2) due to store-TER-aircraft interference given by

$$D_{IT} = T_{I_S}\left(\frac{z_e{}^2 d_w}{144c} - 10\right) + T_{I_I} \qquad 3.2.1.1\text{-r}$$

where:

T_{I_S} is a store-TER-aircraft-interference Mach-correlation factor obtained from Figure 3.2.1.1-33 as a function of Mach number.

z_e, d_w and c were previously defined in the Wing-Pylon-Mounted Fully-Loaded-MER Case.

T_{I_I} is a TER adjacent-store separation factor (ft^2) obtained from Figure 3.2.1.1-34 as a function of Mach number and d_c/d_S where d_c and d_S are defined in the Wing-Pylon-Mounted Fully-Loaded-MER Case.

Wing-Pylon-Mounted Partially Loaded TER

The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by:

$$D_B = D_{ET}\left(1 - \frac{N_{S_T}}{3}\right) + D_{FLT} \qquad 3.2.1.1\text{-s}$$

where

D_{ET} is the empty-TER equivalent-parasite-drag area (ft^2) given by D_B from Equation 3.2.1.1-o.

N_{S_T} is the number of stores attached to the TER.

D_{FLT} is the zero-lift equivalent-parasite-drag area (ft^2) due to a fully loaded TER given by D_B in Equation 3.2.1.1-q.

Fuselage-Tangent-Mounted Stores
(Two or More Single Stores)

The Datcom Method for this configuration is applicable only for 2 or 3 store-row installations mounted on the fuselage bottom surface, and for a Mach-number range of from 0.6 to 0.9. The following additional limitations apply:

1. Same number of stores per row for two- or three-row configurations.

2. Constant fuselage-station location for all stores on a given row.

3. Constant longitudinal space between all stores in tandem, for two- or three-row configurations.

4. Constant lateral space between all stores.

5. Coincident store centerlines for stores in tandem (maximum number of stores in tandem = 3; maximum number of stores/row = 5; staggered store arrangements not included).

6. Effective store-diameter range: 8.0 to 11.5 inches.

7. All stores in one installation must be identical.

Due to the nature of this method, the zero-lift equivalent-parasite-drag area, D_B, is computed for all stores taken together. In order to be consistent with the values of D_B computed by other methods in this section, the entire group of stores is considered to be *one* installation.

The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by:

$$D_B = n_r D_{FR} + D_{IS} K_{NI} \qquad 3.2.1.1\text{-t}$$

where

n_r is the number of stores per row.

D_{FR} is the fuselage-rack equivalent-parasite-drag area and is a function of the number of rows of stores mounted on the fuselage:

$$D_{FR} = a_1 b_1 \text{ (1 row)} \qquad 3.2.1.1\text{-u}$$

$$D_{FR} = a_1 b_1 + a_2 b_2 \text{ (2 rows)} \qquad 3.2.1.1\text{-v}$$

$$D_{FR} = a_1 b_1 + a_2 b_2 + a_3 b_3 \text{ (3 rows)} \qquad 3.2.1.1\text{-w}$$

where

a_1 a_2, and a_3 are store-diameter correlation factors obtained from Figure 3.2.1.1-35 as a function of the maximum store diameter d_S.

b_1, b_2, and b_3 are store-row Mach-correlation factors obtained from Figure 3.2.1.1-36 as a function of Mach number.

D_{IS} is the isolated-store equivalent-parasite-drag area (ft^2) at M = 0.9, given by Equation 3.2.1.1-e.

K_{N1} is a planform and store-location factor given by

$$K_{N1} = K_{D_1} K_{D_2} K_{D_3} K_{D_4} K_{D_5} K_{D_6} K_{D_7} \qquad 3.2.1.1\text{-x}$$

where

K_{D_1} is a store frontal-area factor given by

$$K_{D_1} = K_{S_M} \left(1 + \frac{3S_\pi}{S_B}\right) \qquad 3.2.1.1\text{-y}$$

where

K_{S_M} is a Mach-effect factor for K_{D_1} obtained from Figure 3.2.1.1-37a as a function of Mach number.

S_π is the store maximum cross-sectional area (ft^2).

S_B is the maximum-fuselage frontal area (ft^2).

K_{D_2} is the wing-sweep-and-location factor obtained from Figure 3.2.1.1-37b as a function of wing leading-edge sweep, wing location, and Mach number.

K_{D_3} is a tandem-spacing factor obtained from Figure 3.2.1.1-38a as a function of Mach number and X_{OL}, the ratio of longitudinal spacing between tandem stores to the store length.

K_{D_4} is a lateral-spacing factor obtained from Figure 3.2.1.1-38b as a function of Y_{OD}, the ratio of the minimum lateral distance (excluding fins) between stores to the maximum store diameter.

K_{D_5} and K_{D_6} are store-rows and stores-per-row correlation factors respectively, obtained by using Table 3.2.1.1-A.

TABLE 3.2.1.1-A

K_{D_5} AND K_{D_6} COMPUTATION

Correlation Factor	No. of Store Rows or Stores Per Row	Figure No. or Value
K_{D_5}	1	Figure 3.2.1.1-39a
	2	Figure 3.2.1.1-39b
	3	1.0
K_{D_6}	1	Figure 3.2.1.1-40
	2	Figure 3.2.1.1-41a
	3	Figure 3.2.1.1-41b

It should be noted that K_{D_5} for the case of 3 store rows is only substantiated for $0.6 \leqslant M \leqslant 0.9$.

K_{D_7} is a store longitudinal-location factor obtained from Figure 3.2.1.1-42a as a function of Mach number and x_r, the ratio of the distance between the aircraft nose and the store nose of the most forward store to the aircraft-fuselage length.

Fuselage-Mounted Empty Pylon

The Datcom Method for this configuration is applicable for a pylon-frontal-area range of from 20 to 170 square inches, and only for pylons mounted on the bottom surface of the fuselage. The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by

$$D_B = B_{xx}\left[K_{CJK}\frac{t_{p_{max}}}{0.04}\left(\frac{2}{c_{p_{top}} + c_{p_{low}}}\right)(0.35 + 0.2167R_U)\right] \qquad 3.2.1.1\text{-z}$$

where all of the above terms are defined in the Wing-Mounted-Empty-Pylon Case.

Fuselage-Pylon-Mounted Stores
(Two or More Single Stores)

The Datcom Method for this configuration is subject to the same limitations given for the Fuselage-Tangent-Mounted Stores Case. Due to the nature of the method, the zero-lift equivalent-parasite-drag area, D_B, is computed for all stores taken together. In order to be consistent with the values of D_B computed by other methods in this section, the entire group of stores is considered to be *one* installation. The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by

$$D_B = n_P D_{LPF} + n_r D_{FR} + K_{SD} K_{PD} K_{NI} D_{IS} \qquad 3.2.1.1\text{-aa}$$

where

n_P is the number of pylons.

D_{LPF} is the zero-lift equivalent-parasite-drag area (ft^2) due to the fuselage-mounted empty pylon given by D_B in Equation 3.2.1.1-z with R_U = 3.0.

n_r is the number of stores per row.

D_{FR} is the fuselage-rack equivalent-parasite-drag-area (ft^2) contribution given by Equations 3.2.1.1-u, v, w.

K_{SD} is a store-depth factor obtained from Figure 3.2.1.1-42b as a function of Mach number and X_{OL}, the ratio of longitudinal spacing between tandem stores to the store length.

K_{PD} is a pylon-depth factor obtained from Figures 3.2.1.1-43a through -43o as a function of Mach number, number of rows, number of stores per row, and H_{OD} where

$$H_{OD} = \frac{h_p + 1.5}{d_S} \qquad 3.2.1.1\text{-bb}$$

where

h_p is the average pylon height (in.).

d_S is the maximum store diameter (in.).

K_{NI} is a planform and store-location factor defined by Equation 3.2.1.1-x.

D_{IS} is the isolated-store equivalent-parasite-drag area (ft^2) at M = 0.9, given by Equation 3.2.1.1-e.

Fuselage-Tangent-Mounted Single Store
(One Installation)

The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by

$$D_B = (1 + K_{IF})(D_{PR} + D_{IS}) \qquad 3.2.1.1\text{-cc}$$

where

K_{IF} is an installation factor obtained from Figures 3.2.1.1-51a through -51g for single stores, as a function of Mach number, fuselage bottom surface shape (bottom surface either curved or straight), the maximum depth of the store installation measured from the bottom surface of wing z (in.), and the average pylon height (in.) h_p.

D_{PR} is the pylon-rack equivalent-parasite-drag area (ft^2) given by Figure 3.2.1.1-22a as a function of Mach number.

D_{IS} is the isolated-store equivalent-parasite-drag area (ft^2) at M = 0.9, given by Equation 3.2.1.1-e.

Fuselage-Tangent-Mounted MER
(One Installation)

The Datcom Method for this configuration is limited to a single MER installation tangent mounted on the bottom of the fuselage. The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by

$$D_B = (1 + K_{IF})(D_{PR} + 6D_{IS} + D_{MSB} + D_{MRF}) \qquad 3.2.1.1\text{-dd}$$

where

K_{IF} is an installation factor for tangent-mounted stores obtained from Figures 3.2.1.1-54a through -54g for MER installations.

D_{PR} is the pylon-rack equivalent-parasite-drag area (ft^2) given by Figure 3.2.1.1-22a as a function of Mach number.

D_{IS} is the isolated-store equivalent-parasite-drag area (ft^2) at $M = 0.9$, given by Equation 3.2.1.1-e.

D_{MSB} is the MER-sway-brace equivalent-parasite-drag area (ft^2) obtained from Figure 3.2.1.1-25 as a function of Mach number.

D_{MRF} is the zero-lift equivalent-parasite-drag area (ft^2) due to MER-rack-to-fuselage interference obtained from Figure 3.2.1.1-57 as a function of Mach number.

Fuselage-Pylon-Mounted Single Store
(One Installation)

The Datcom Method for this configuration is applicable for a pylon-frontal-area range of from 20 to 170 square inches, and only for pylons mounted on the bottom surface of the fuselage. The zero-lift equivalent-parasite-drag area (ft^2) due to the basic installation is given by

$$D_B = (1 + K_{IF})(D_{PR} + D_{IS} + D_{ILP}) \qquad 3.2.1.1\text{-ee}$$

where

K_{IF} is an installation factor as defined for the Fuselage-Tangent-Mounted Single-Store Case, obtained from Figures 3.2.1.1-51a through -51g.

D_{PR} is the pylon-rack equivalent-parasite-drag area (ft^2) given by Figure 3.2.1.1-22a as a function of Mach number.

D_{IS} is the isolated-store equivalent-parasite-drag area (ft^2) at $M = 0.9$, given by Equation 3.2.1.1-e.

D_{ILP} is the equivalent-parasite-drag area (ft^2) of the installed loaded pylon given by D_B from Equation 3.2.1.1-z with $R_U = 3.0$.

Fuselage-Pylon-Mounted MER
(One Installation)

The Datcom Method for this configuration has the same limitations as the previous case. The zero-lift equivalent-parasite-drag area (ft^2) due to the basic store installation is given by

$$D_B = (1 + K_{IF})(D_{PR} + 6D_{IS} + D_{ILP} + D_{MRF} + D_{MSB}) \qquad 3.2.1.1\text{-ff}$$

where

K_{IF} is an installation factor as defined for the Fuselage-Tangent-Mounted MER Case, obtained from Figures 3.2.1.1-54a through 3.2.1.1-54g.

D_{PR} is the pylon-rack equivalent-parasite-drag area (ft^2) given by Figure 3.2.1.1-22a as a function of Mach number.

D_{IS} is the isolated-store equivalent-parasite-drag area (ft^2) at M = 0.9, given by Equation 3.2.1.1-e.

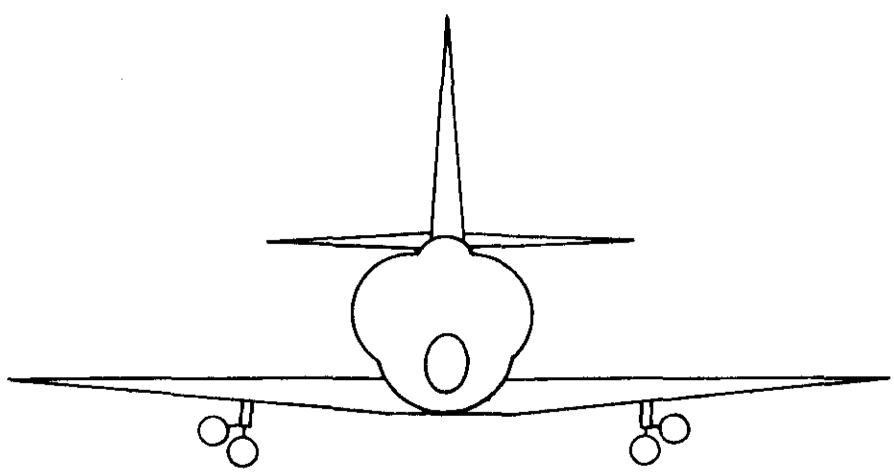
D_{ILP} is the installed-loaded-pylon equivalent-parasite-drag area (ft^2) given by D_B from Equation 3.2.1.1-z with R_U = 3.0.

D_{MRF} is the zero-lift equivalent-parasite-drag area (ft^2) due to MER-rack-to-fuselage interference obtained from Figure 3.2.1.1-57 as a function of Mach number.

D_{MSB} is the MER-sway-brace equivalent-parasite-drag area (ft^2) obtained from Figure 3.2.1.1-25 as a function of Mach number.

Sample Problem

Given: A swept-wing subsonic fighter aircraft (Reference 2) symmetrically loaded at the inboard wing stations with pylon-mounted TER's, each containing two 500-lb bombs.



FRONT VIEW

Aircraft Data. $c = 121.5$ in.

Store Data:

$S_\pi = 0.785\ ft^2$ $\qquad C_{D_\pi} = 0.11$ $\qquad d_S = 12$ in.

Installation Data:

$S_P = 51.3\ in.^2$ $\qquad t_{p_{max}} = 4.7$ in. $\qquad c_{p_{top}} = 66.9$ in. $\qquad c_{p_{low}} = 66.9$ in.

$x_{AFT} = -49.6$ in. $\qquad x_{FWD} = -10.4$ in. $\qquad d_c = 3.2$ in. $\qquad d_w = 25.6$ in.

$z_e = 70.4$ in.

Additional Data:

$M = 0.6$

Compute: (Method -- Wing-Pylon-Mounted Partially Loaded TER)

Since the installation is symmetrical, only one side need be computed.

$$D_B = D_{ET}\left(1 - \frac{N_{S_T}}{3}\right) + D_{FLT} \qquad \text{(Equation 3.2.1.1-s)}$$

Expand the above equation to identify the terms which need to be computed:

$$D_{ET} = D_{ILP} + D_{TSB} + D_{ITR} \qquad \text{(Equation 3.2.1.1-o)}$$

$$D_{FLT} = D_{ET} + 3D_{IS} + D_{IT} \qquad \text{(Equation 3.2.1.1-q)}$$

Find D_{ILP}:

$$\frac{x_{AFT}}{c} = \frac{-49.6}{121.5} = -0.408$$

$B_{xx} = 0.106$ (Figure 3.2.1.1-20)

$K_{xx} = 0.16$ (Figure 3.2.1.1-21a)

$K_{CJK} = 0.25$ (Figure 3.2.1.1-21b)

$D_{PR} = 0.088\ ft^2$ (Figure 3.2.1.1-22a)

$$D_{ILP} = \left(B_{xx} + K_{xx}\frac{S_P}{144}\right)\left[K_{CJK}\frac{t_{p_{max}}}{0.04}\left(\frac{2}{c_{p_{top}} + c_{p_{low}}}\right)(0.35 + 0.2167R_U)\right]$$

$$+ D_{PR} \qquad \text{(Equation 3.2.1.1-a)}$$

$$= \left[0.106 + (0.16)\left(\frac{51.3}{144}\right)\right]\left\{(0.25)\frac{(4.7)}{(0.04)}\ \frac{(2)[0.35 + (0.2167)3]}{(66.9 + 66.9)}\right\} + 0.088$$

$$= 0.160\ ft^2$$

Find D_{TSB}:

$$D_{TSB} = 0.180\ ft^2 \quad \text{(Figure 3.2.1.1-30)}$$

Find D_{ITR}:

$$\frac{x_{FWD}}{c} = \frac{-10.4}{121.5} = -0.0856$$

$$R_{F_T} = 0 \qquad \text{(Figure 3.2.1.1-31)}$$

$$R_{A_T} = 0.300 \qquad \text{(Figure 3.2.1.1-32)}$$

$$D_{ITR} = R_{F_T} + R_{A_T} = 0 + 0.300 = 0.300\ ft^2 \qquad \text{(Equation 3.2.1.1-p)}$$

Find D_{ET}:

$$D_{ET} = D_{ILP} + D_{TSB} + D_{ITR} \qquad \text{(Equation 3.2.1.1-o)}$$

$$= 0.160 + 0.180 + 0.300$$

$$= 0.640\ ft^2$$

Find D_{IS}:

$$D_{IS} = S_\pi C_{D_\pi} = (0.785)(0.11) \qquad \text{(Equation 3.2.1.1-e)}$$

$$= 0.0864\ ft^2$$

Find D_{IT}:

$$T_{IS} = 0.005 \qquad \text{(Figure 3.2.1.1-33)}$$

$$\frac{d_c}{d_S} = \frac{3.2}{12} = 0.267$$

$$T_{I_I} = 0.40 \quad \text{(Figure 3.2.1.1-34)}$$

$$D_{I_T} = T_{I_S}\left(\frac{z_e^2\, d_w}{144c} - 10\right) + T_{I_I} \quad \text{(Equation 3.2.1.1-r)}$$

$$= 0.005\left[\frac{(70.4)^2(25.6)}{(144)(121.5)} - 10\right] + 0.40$$

$$= 0.386 \text{ ft}^2$$

Find D_{FLT}:

$$D_{FLT} = D_{ET} + 3D_{IS} + D_{IT} \quad \text{(Equation 3.2.1.1-q)}$$

$$= 0.640 + (3)(0.0864) + 0.386$$

$$= 1.285 \text{ ft}^2$$

Solution:

$$D_B = D_{ET}\left(1 - \frac{N_{S_T}}{3}\right) + D_{FLT} \quad \text{(Equation 3.2.1.1-s)}$$

$$= 0.640\left(1 - \frac{2}{3}\right) + 1.285 = 1.498 \text{ ft}^2 \text{ (one side)}$$

This result is used in the Sample Problem of Paragraph A of Section 3.2.3 as part of the total-drag-increment computation.

B. TRANSONIC

The method presented in Paragraph A of this section is also valid for transonic speeds with the exception of the following fuselage-mounted configurations which are limited to $M \leqslant 0.9$:

1. Two or more stores tangent-mounted in single-carriage modes.

2. Two or more stores pylon-mounted in single-carriage modes.

The method presented in Paragraph A for the Wing-Pylon-Mounted Single-Store Case requires additional equations in the transonic speed range. Separate equations for D_B are required at discrete Mach numbers as in the subsonic case. To obtain values at intermediate Mach numbers, interpolation must be used.

Wing-Pylon-Mounted Single Store

For M = 0.9:

$$D_B = B \qquad \text{(Equation 3.2.1.1-h)}$$

where

B is given by Equation 3.2.1.1-d.

For M = 0.95:

$$D_B = 0.77\,[(B + T_A S_\pi)\,P - B] + B \qquad 3.2.1.1\text{-gg}$$

where

B is given by Equation 3.2.1.1-d.

T_A is a transonic-supersonic correlation factor obtained from Figure 3.2.1.1-58a as a function of x_{FWD}, x_{AFT}, and c where

- x_{FWD} is the longitudinal distance from the local wing leading edge to the store/pylon nose (in.), positive for store nose aft of the local wing leading edge. (See Sketch (a).)
- x_{AFT} is the longitudinal distance (in.) from the local wing trailing edge to the trailing edge of the store installation (or pylon trailing edge for the empty pylon case), positive in the aft direction. (See Sketch (a).)
- c is the local wing chord at the local store or pylon station (in.). (See Sketch (a).)

S_π is the maximum store cross-sectional area (ft^2).

P is a clean-aircraft drag-rise factor obtained from Figure 3.2.1.1-58b as a function of the clean-aircraft drag-rise factor, C'_{D_0}, where

$$C'_{D_0} = \frac{C_{D_0} \text{ at } M = 1.05}{C_{D_0} \text{ at } M = 0.6} \qquad 3.2.1.1\text{-hh}$$

where

C_{D_0} is the clean-aircraft zero-lift drag coefficient from test data or estimated from Section 4.5.3.1.

For $M = 1.05$:

$$D_B = (B + T_A S_\pi)P \qquad 3.2.1.1\text{-ii}$$

where B, T_A, S_π, and P are defined above.

For $M = 1.20$:

$$D_B = B + T_A S_\pi \qquad 3.2.1.1\text{-jj}$$

where B, T_A, and S_π are defined above.

The user is cautioned that the accuracy of the method is less than that of the subsonic speed range, and test data should be used whenever possible.

C. SUPERSONIC

The method presented in Paragraph A of this section is also valid for supersonic speeds within the Mach-number limits specified in Table 3.2-A. The method presented in Paragraph A for the Wing-Pylon-Mounted Single-Store Case requires the following modification in the supersonic speed range.

Wing-Pylon-Mounted Single Store

For $M = 1.60$ to $M = 2.00$:

D_B is obtained from Figures 3.2.1.1-59a and -59b as a function of $B + T_A S_\pi$.

The user should exercise caution in extrapolating the method beyond the specified Mach-number range.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer. McDonnell Douglas Corporation Rept. DAC-67425, 1968. (U)

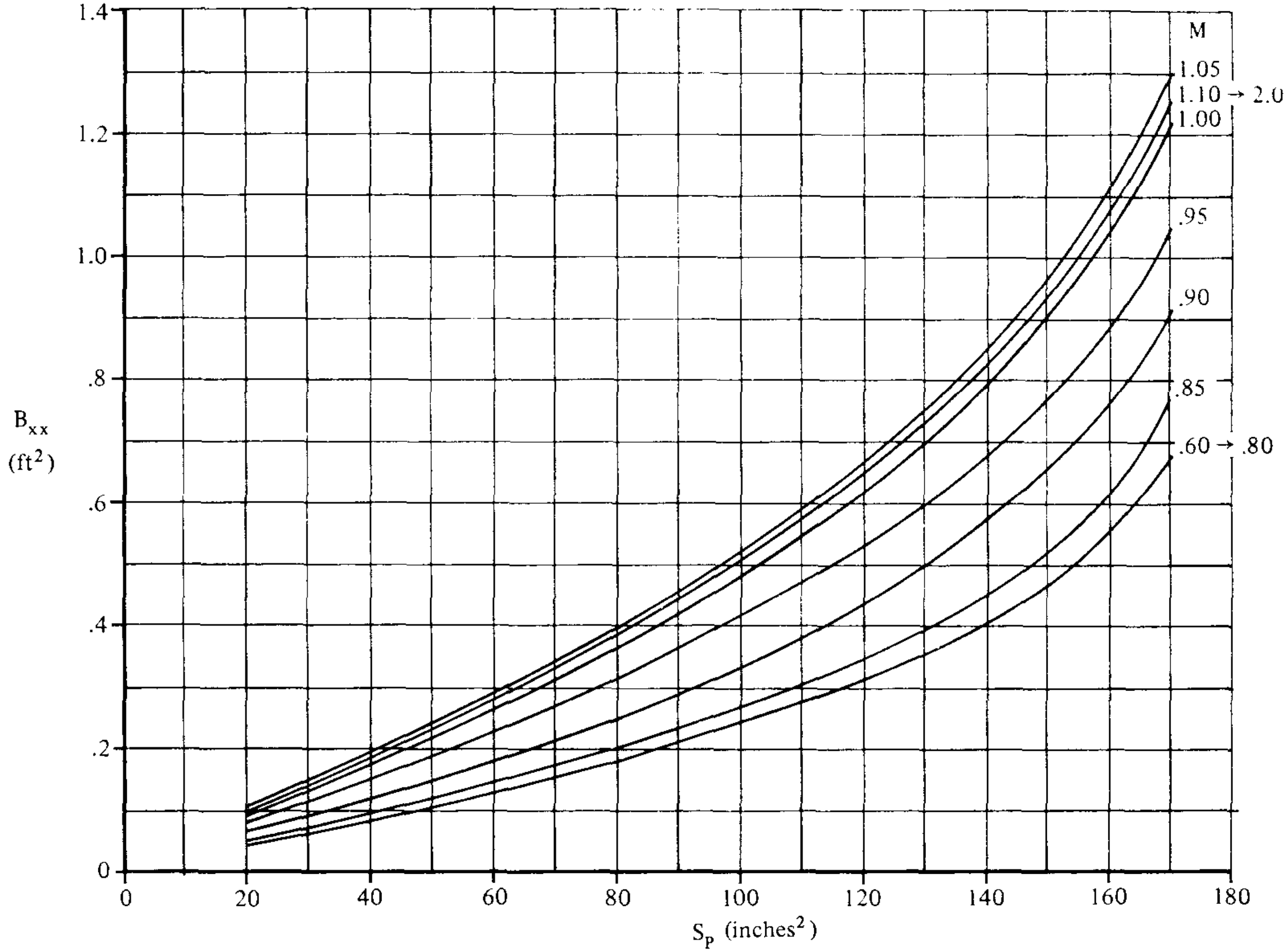


FIGURE 3.2.1.1-20 EMPTY-PYLON DRAG FACTOR

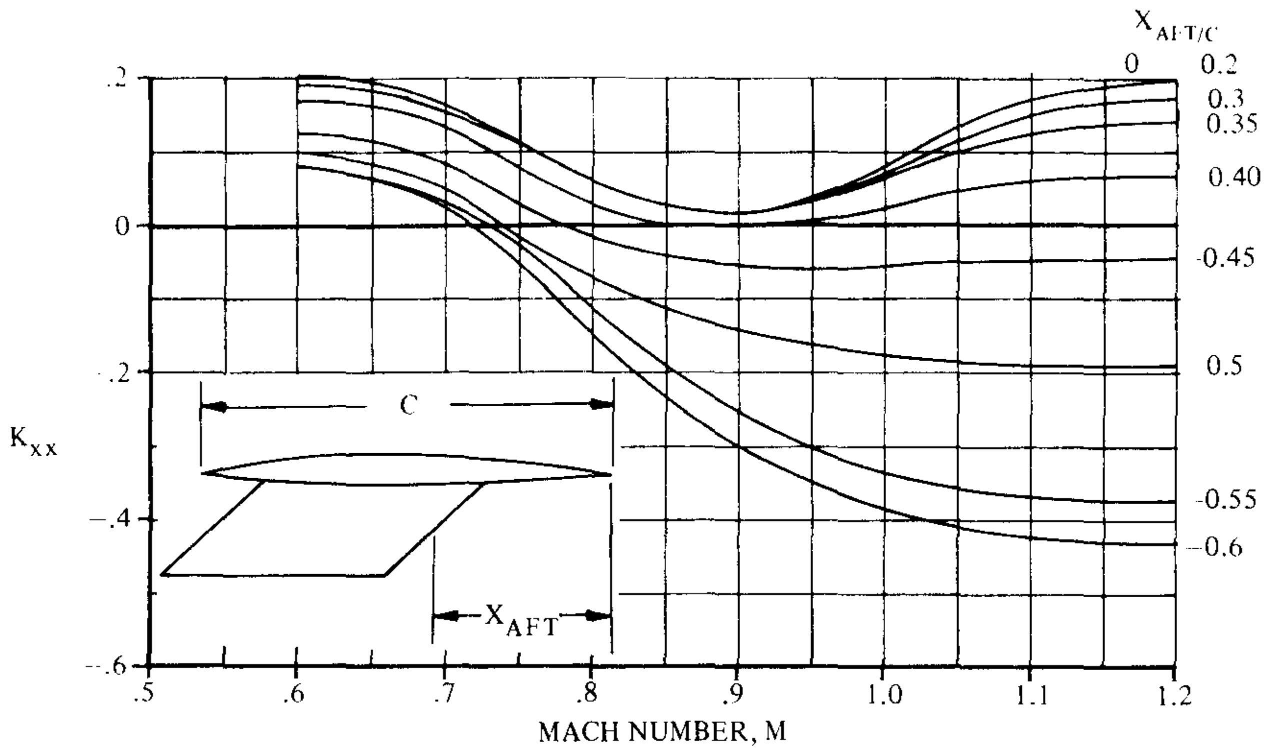


FIGURE 3.2.1.1-21a EMPTY-PYLON CORRELATION RATIO

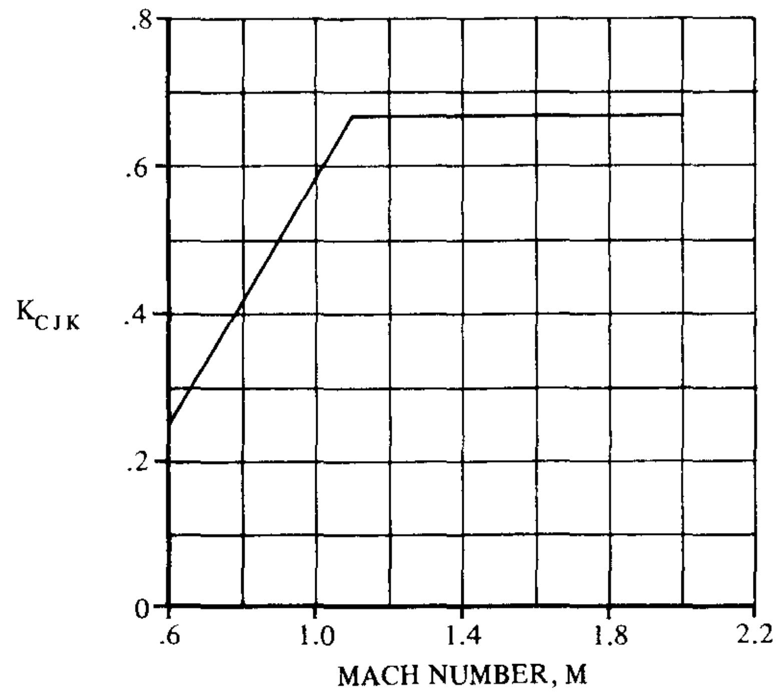


FIGURE 3.2.1.1-21b PYLON MACH-NUMBER CORRELATION PARAMETER

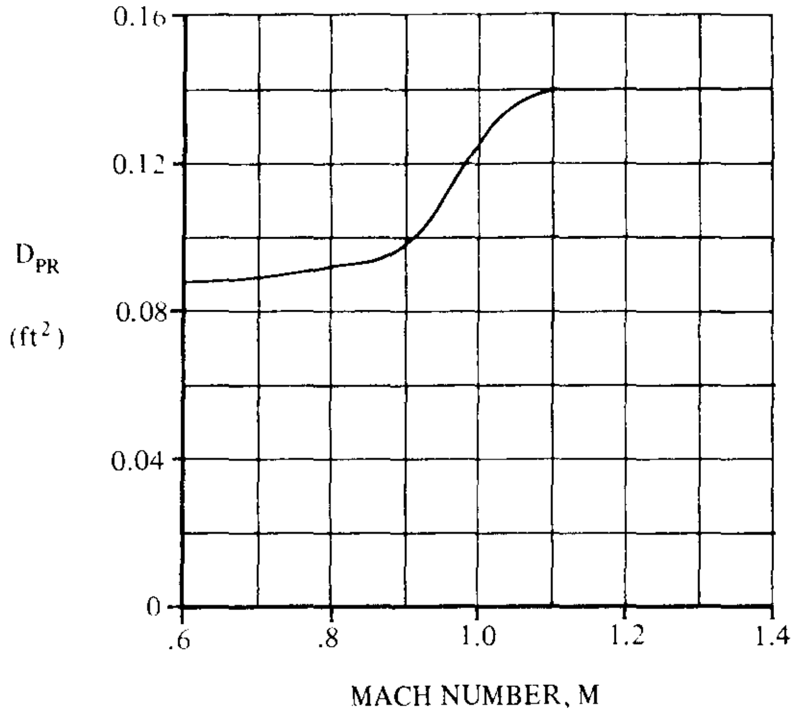


FIGURE 3.2.1.1-22a PYLON-RACK EQUIVALENT-PARASITE-DRAG AREA

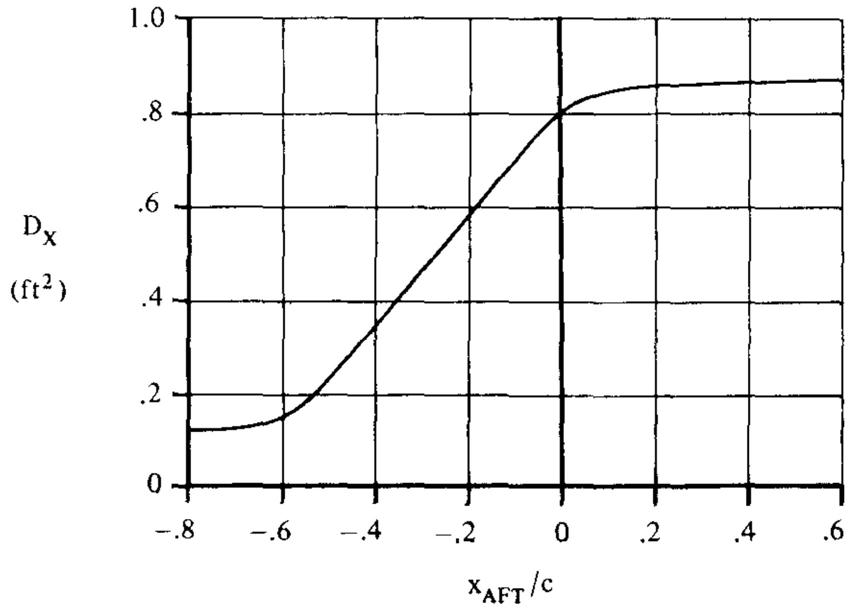


FIGURE 3.2.1.1-22b EQUIVALENT-PARASITE-DRAG AREA DUE TO STORE-TO-AIRCRAFT INTERFERENCE

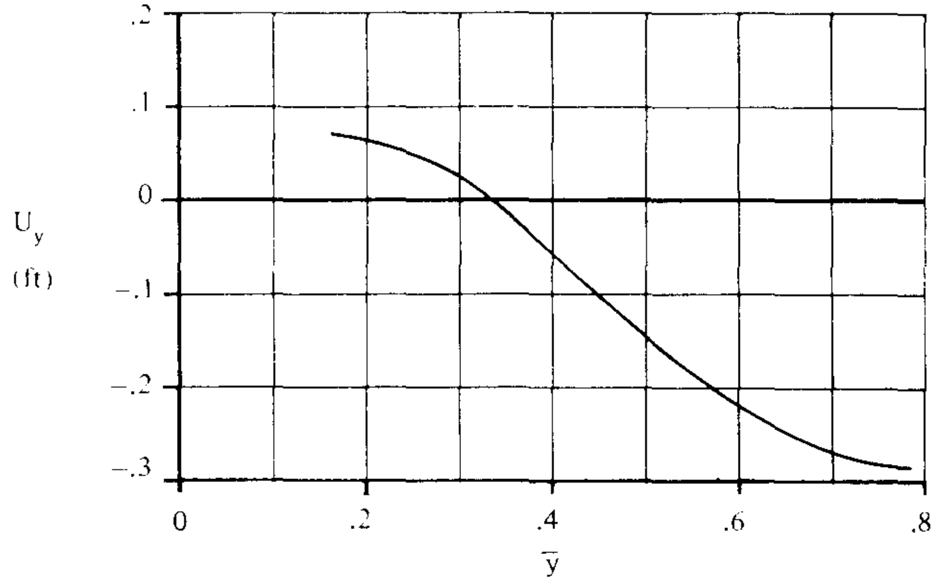


FIGURE 3.2.1.1-23a LATERAL DRAG INTERFERENCE FACTOR

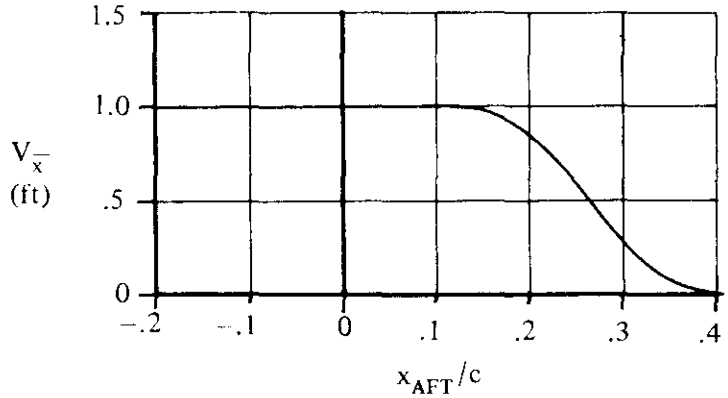


FIGURE 3.2.1.1-23b LONGITUDINAL DRAG INTERFERENCE FACTOR

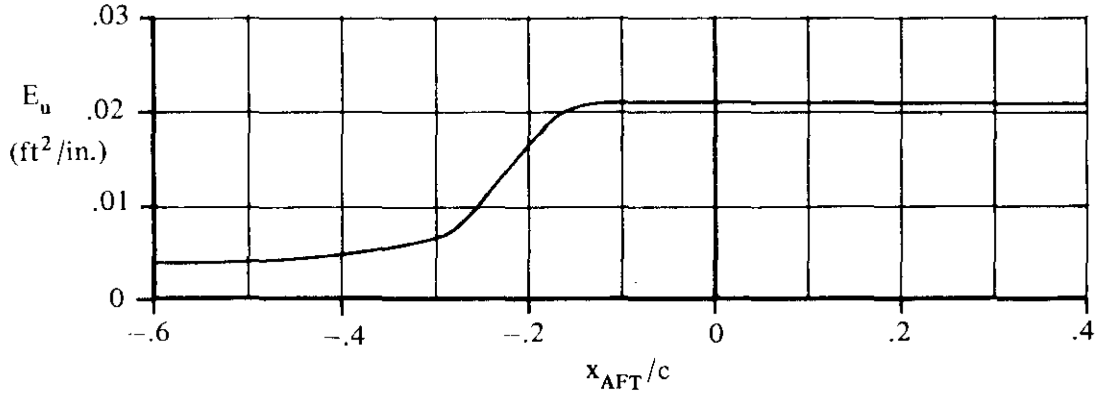


FIGURE 3.2.1.1-23c PYLON-HEIGHT INTERFERENCE FACTOR

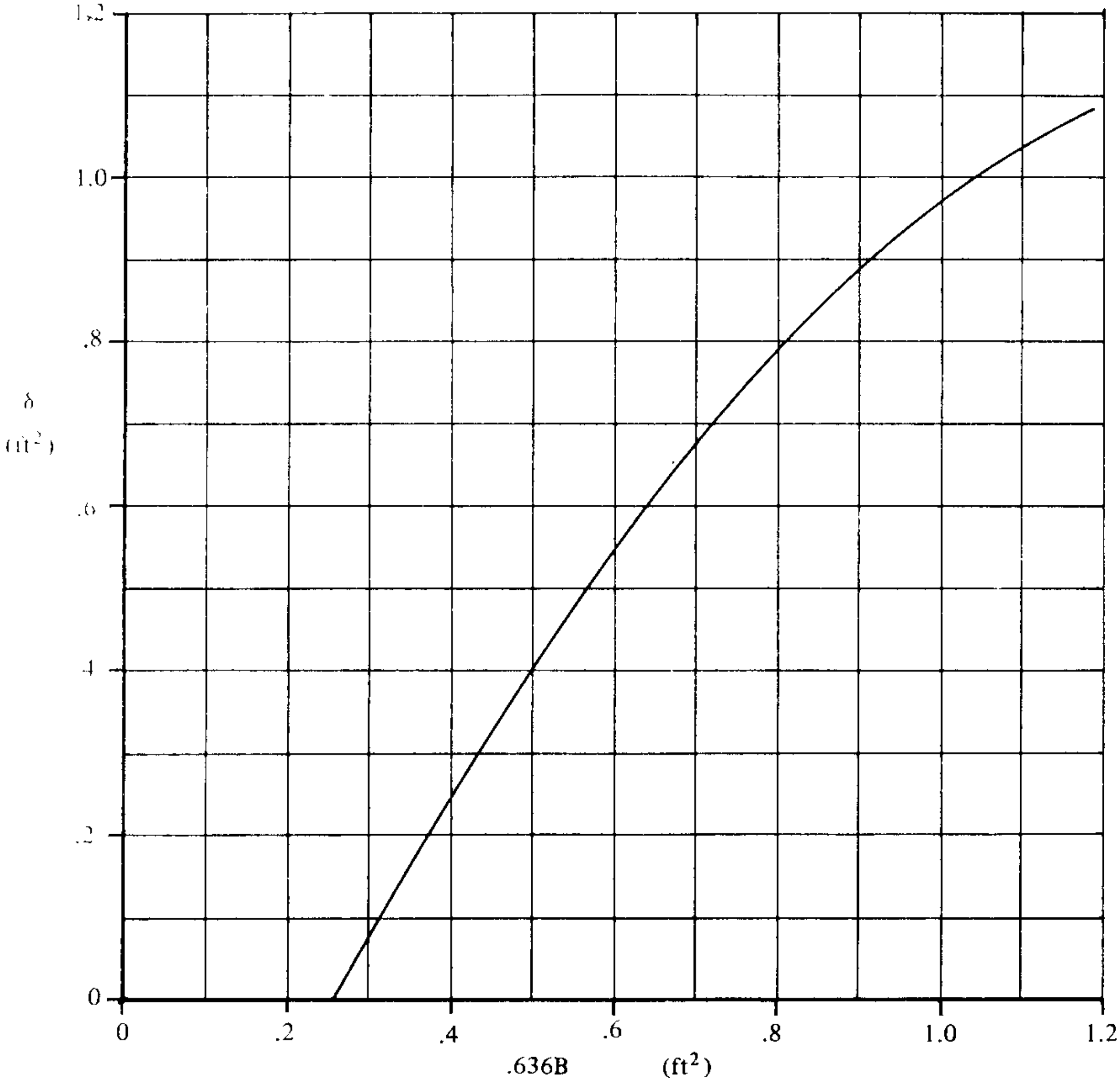


FIGURE 3.2.1.1-24 EQUIVALENT-PARASITE-DRAG AREA

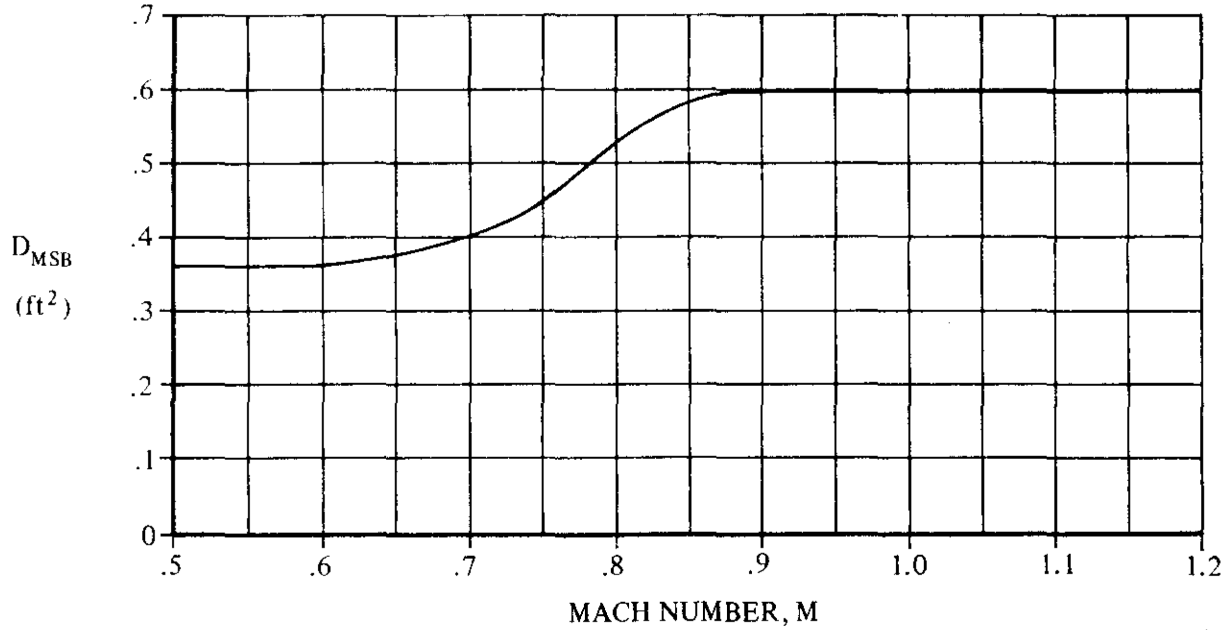


FIGURE 3.2.1.1-25 MER SWAY-BRACE EQUIVALENT-PARASITE-DRAG AREA

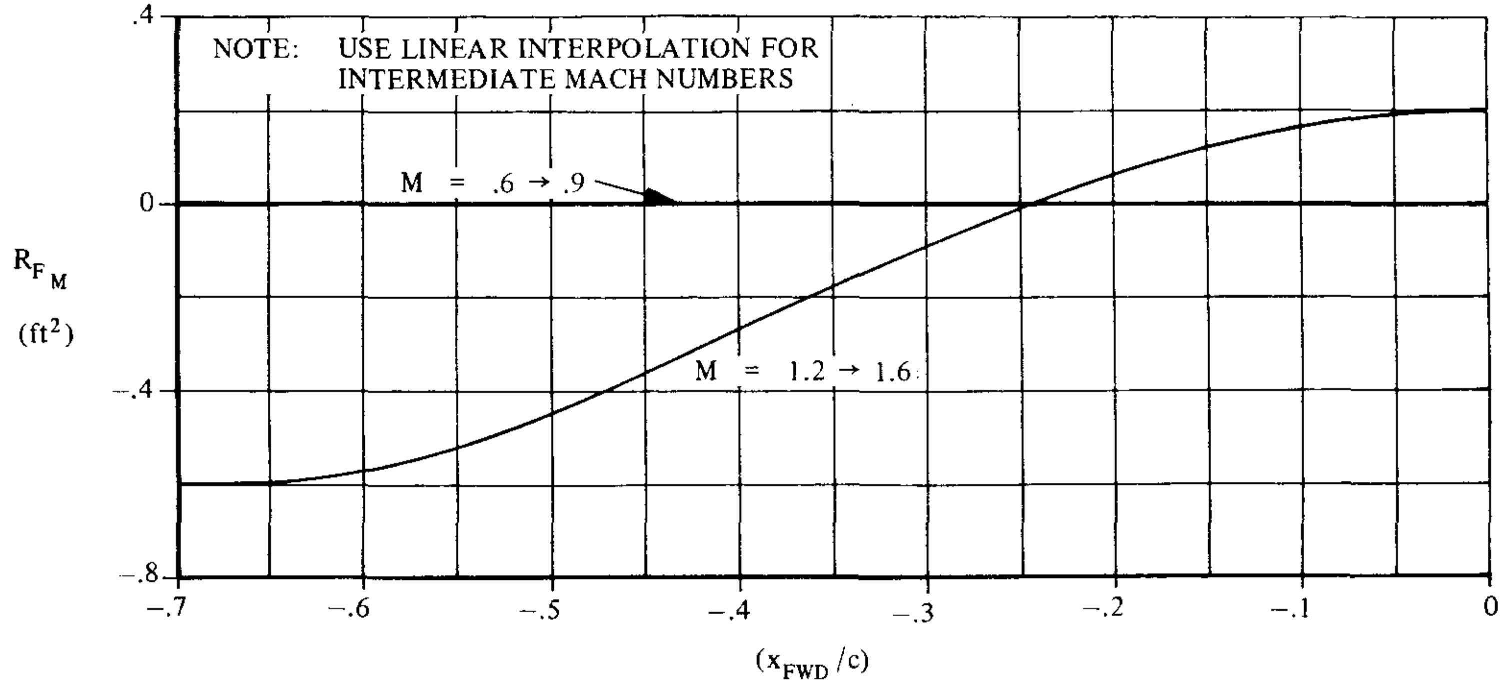


FIGURE 3.2.1.1-26 MER FORWARD-LONGITUDINAL-PLACEMENT TERM

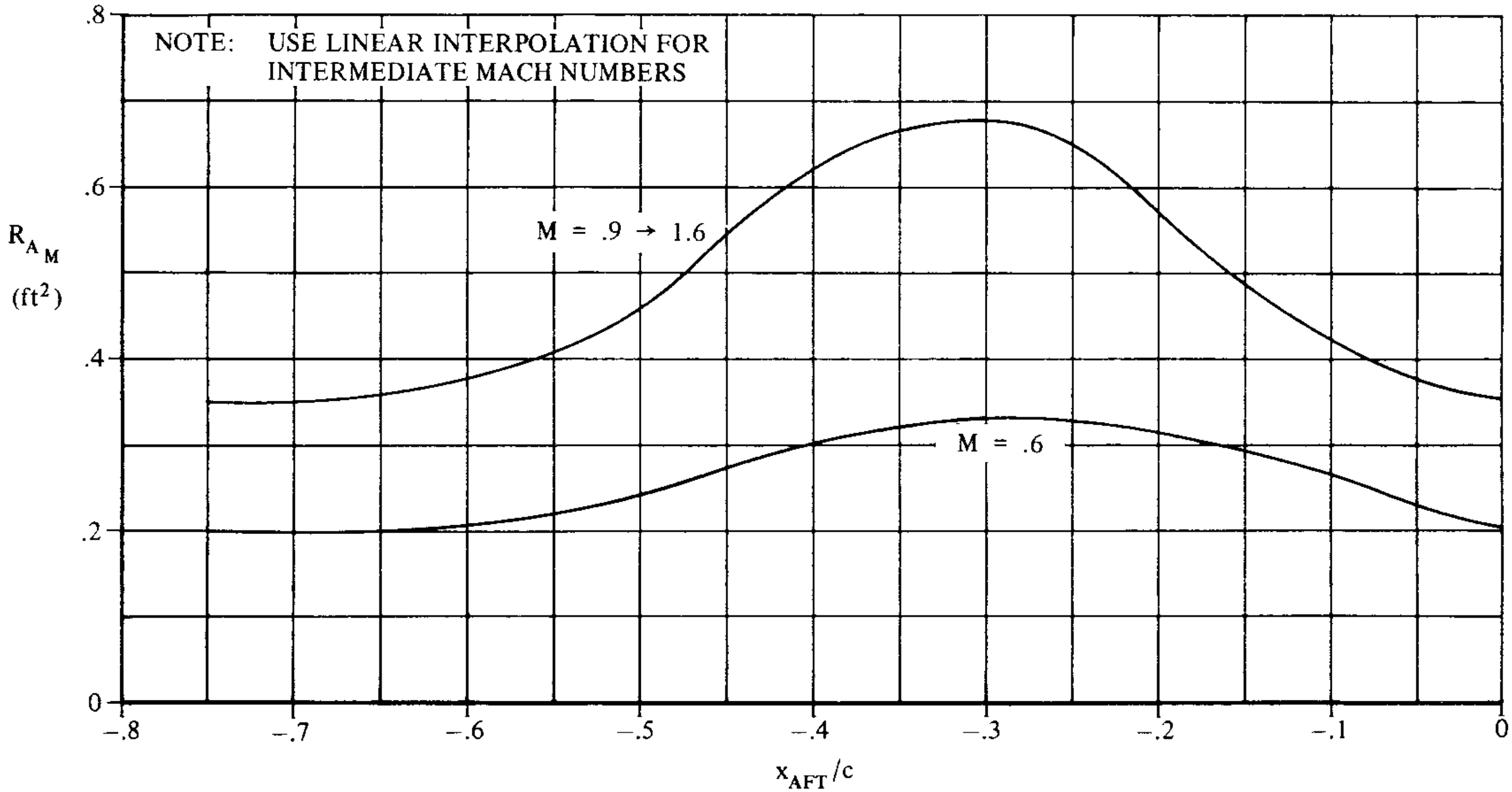


FIGURE 3.2.1.1-27 MER AFT LONGITUDINAL-PLACEMENT TERM

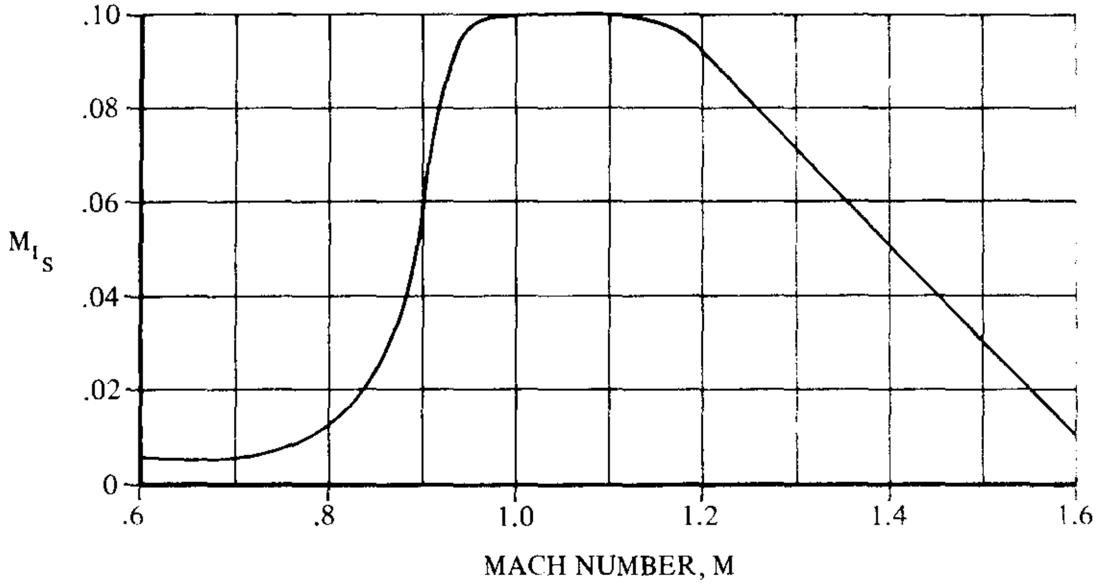


FIGURE 3.2.1.1-28 STORE-MER-AIRCRAFT-INTERFERENCE MACH-CORRELATION FACTOR

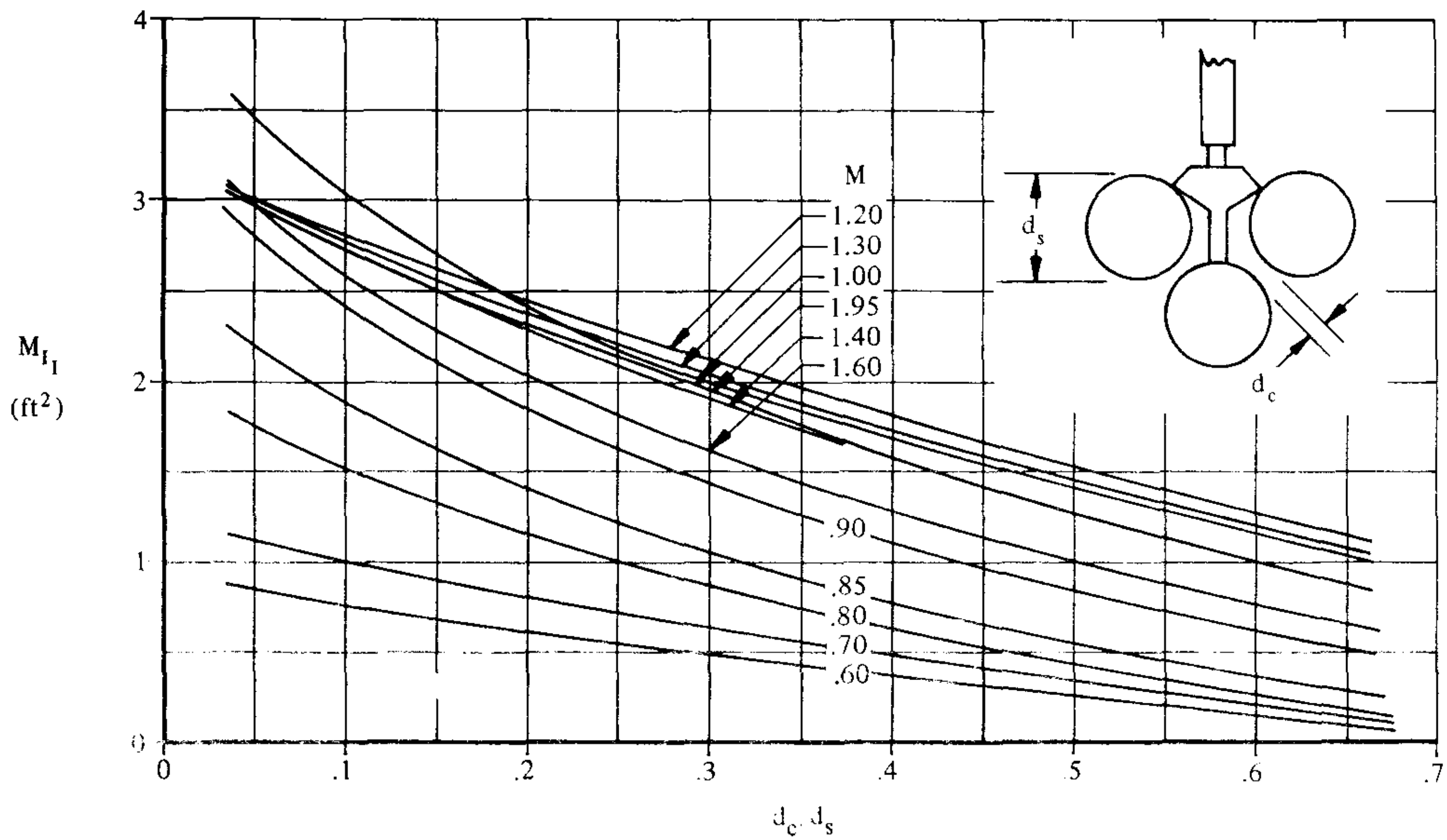


FIGURE 3.2.1.1-29 MER ADJACENT-STORE SEPARATION FACTOR

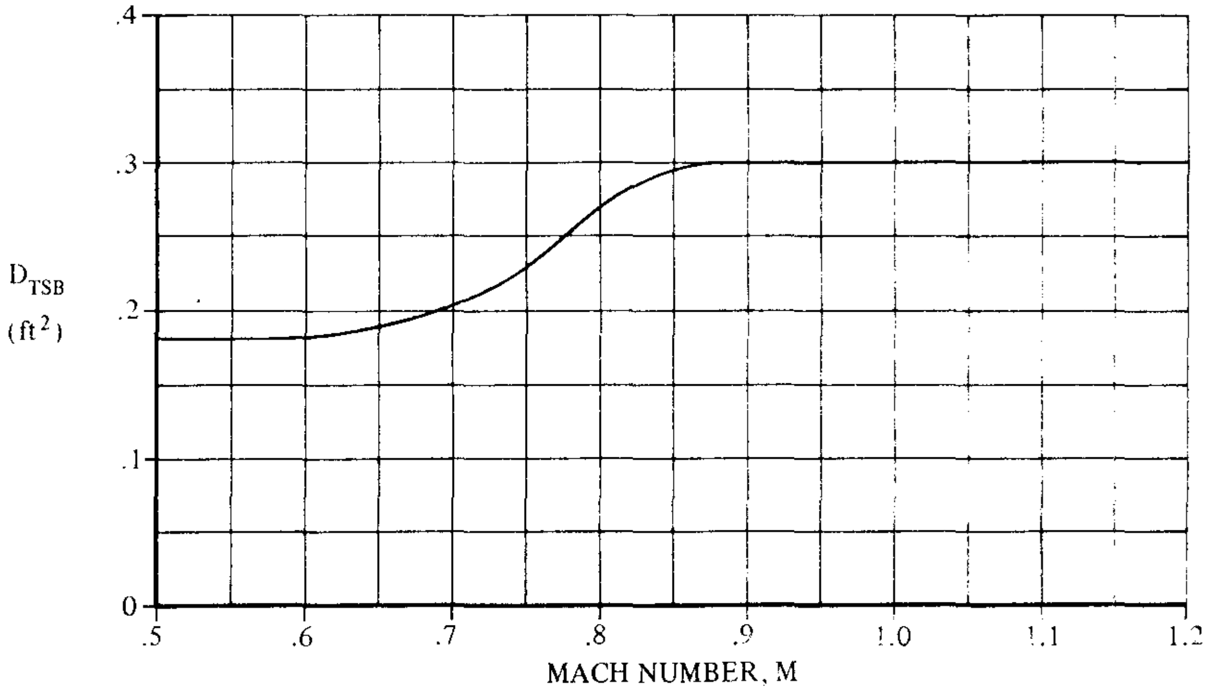


FIGURE 3.2.1.1-30 TER SWAY-BRACE EQUIVALENT-PARASITE-DRAG AREA

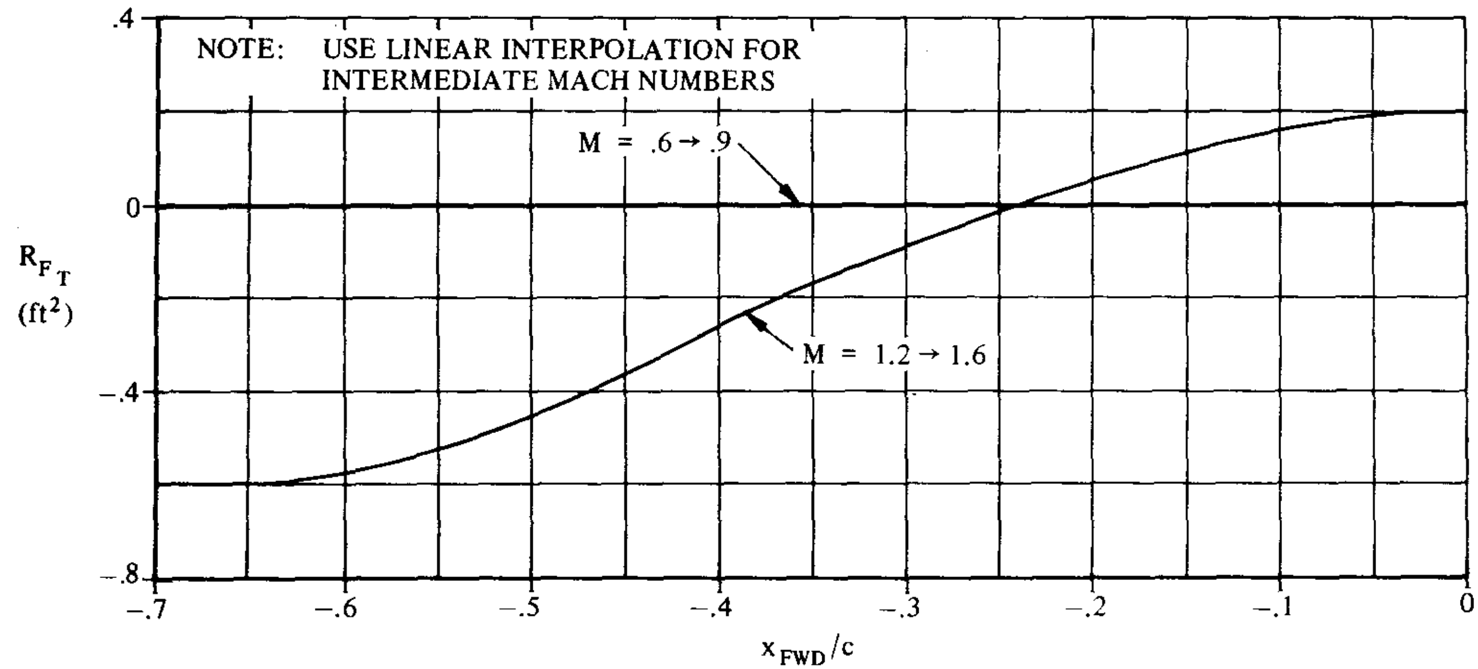


FIGURE 3.2.1.1-31 TER FORWARD-LONGITUDINAL-PLACEMENT TERM

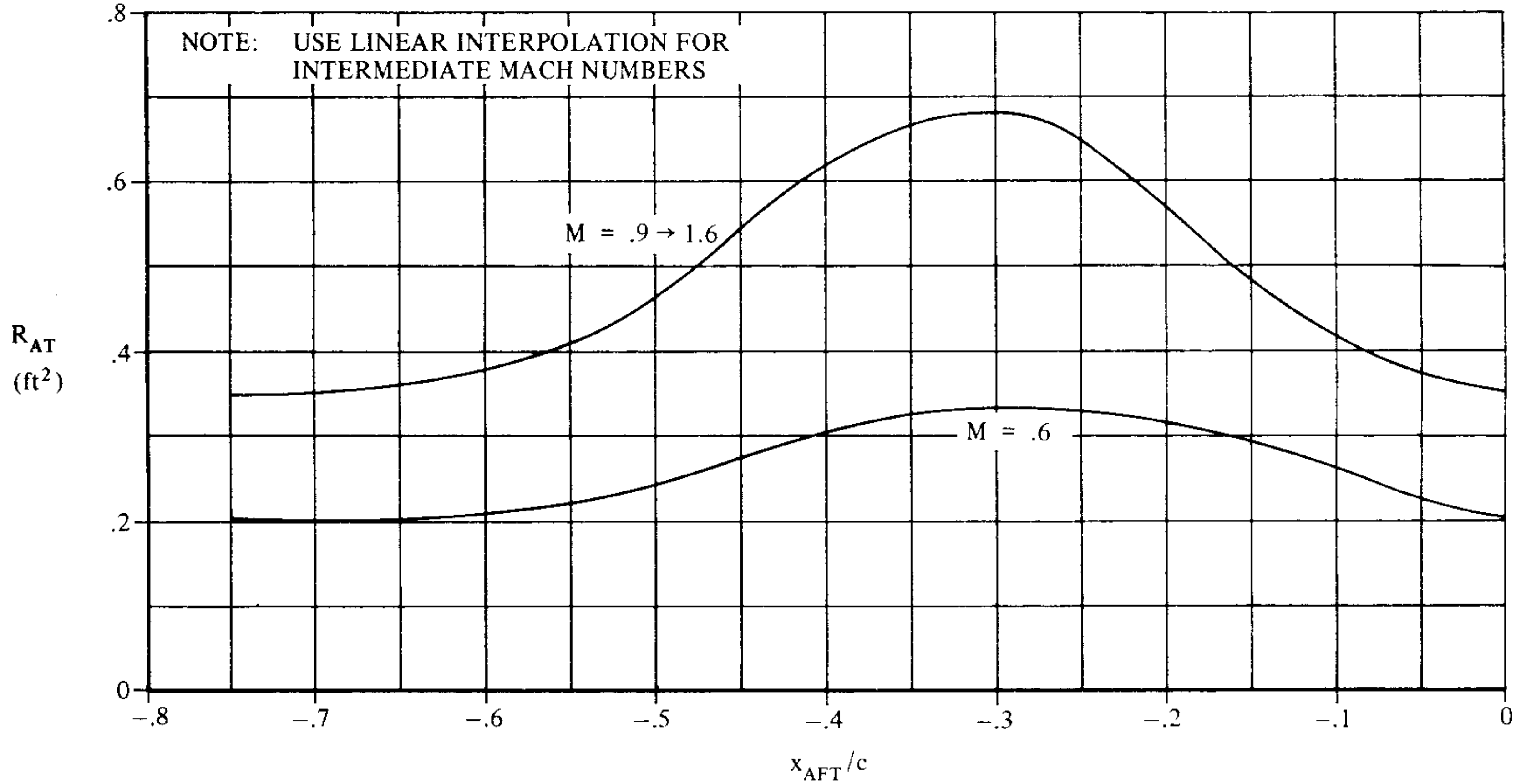


FIGURE 3.2.1.1-32 TER AFT-LONGITUDINAL-PLACEMENT TERM

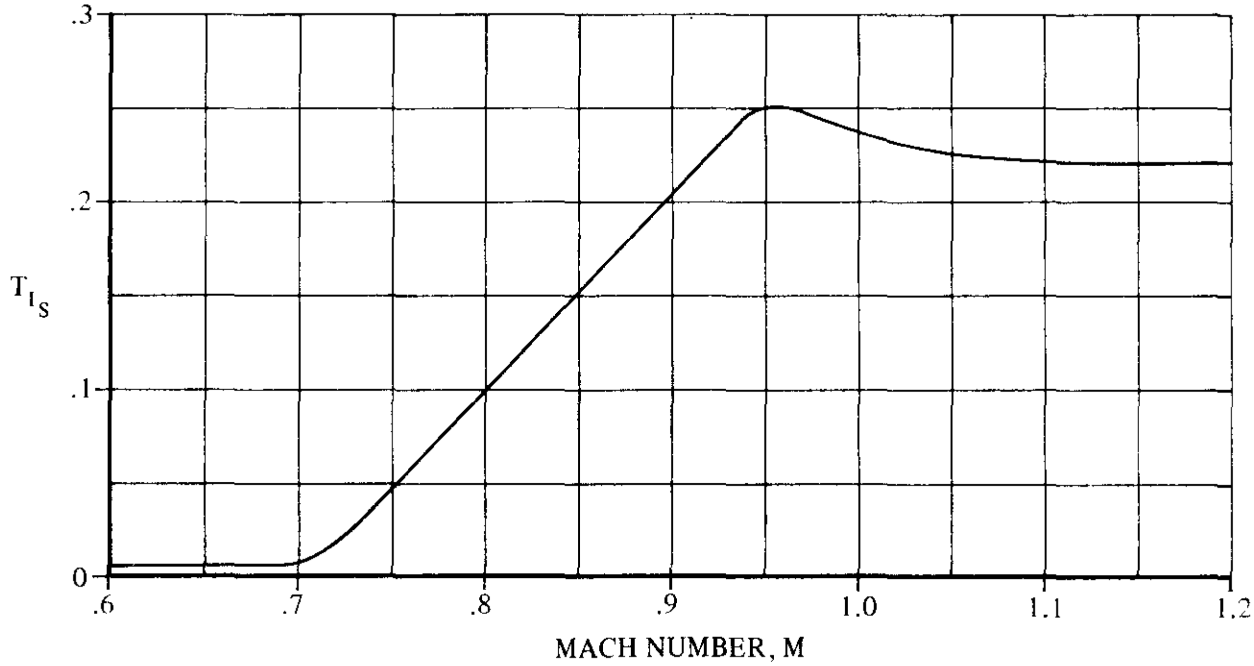


FIGURE 3.2.1.1-33 STORE-TER-AIRCRAFT-INTERFERENCE MACH-CORRELATION FACTOR

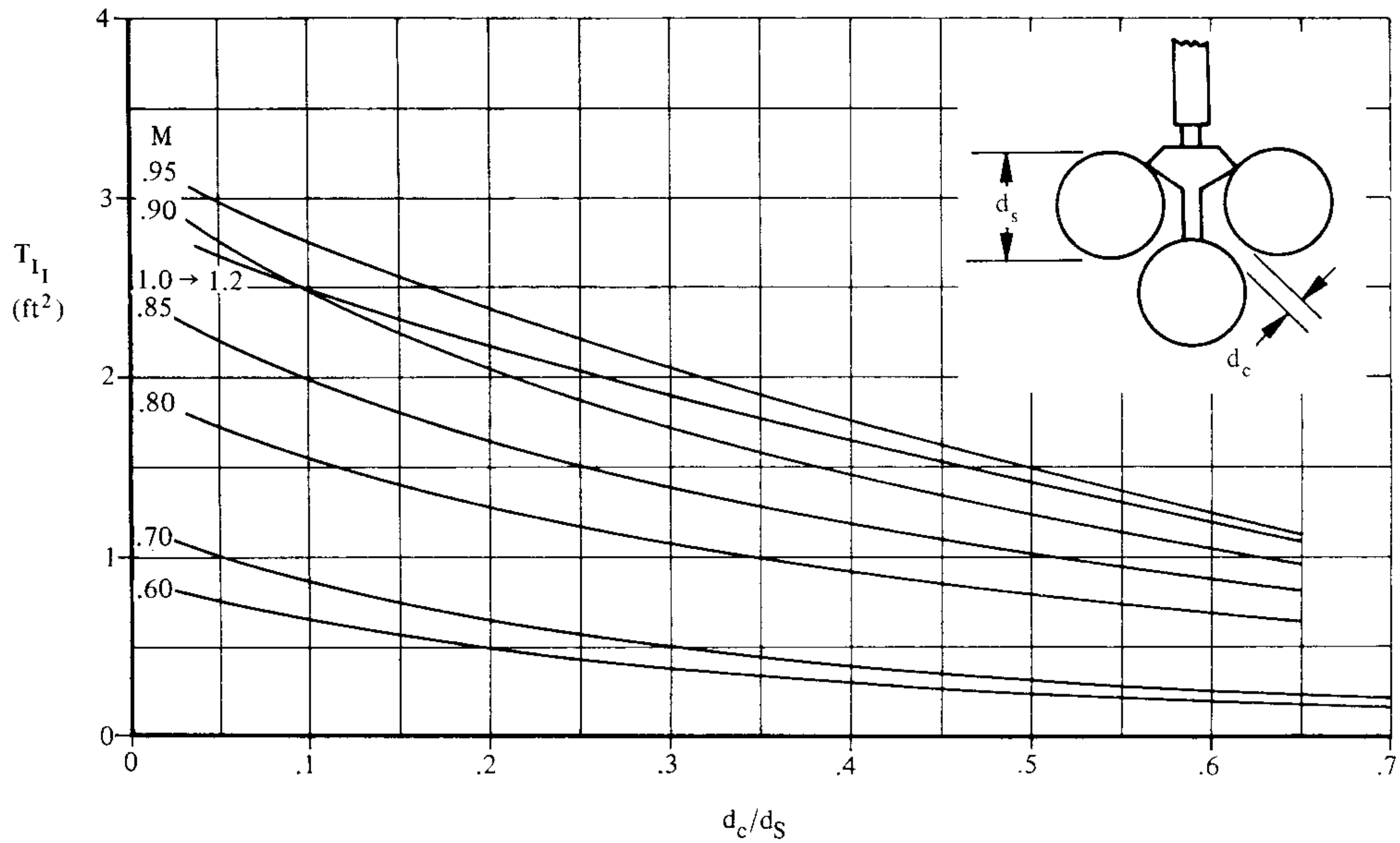


FIGURE 3.2.1.1-34 TER ADJACENT-STORE SEPARATION FACTOR

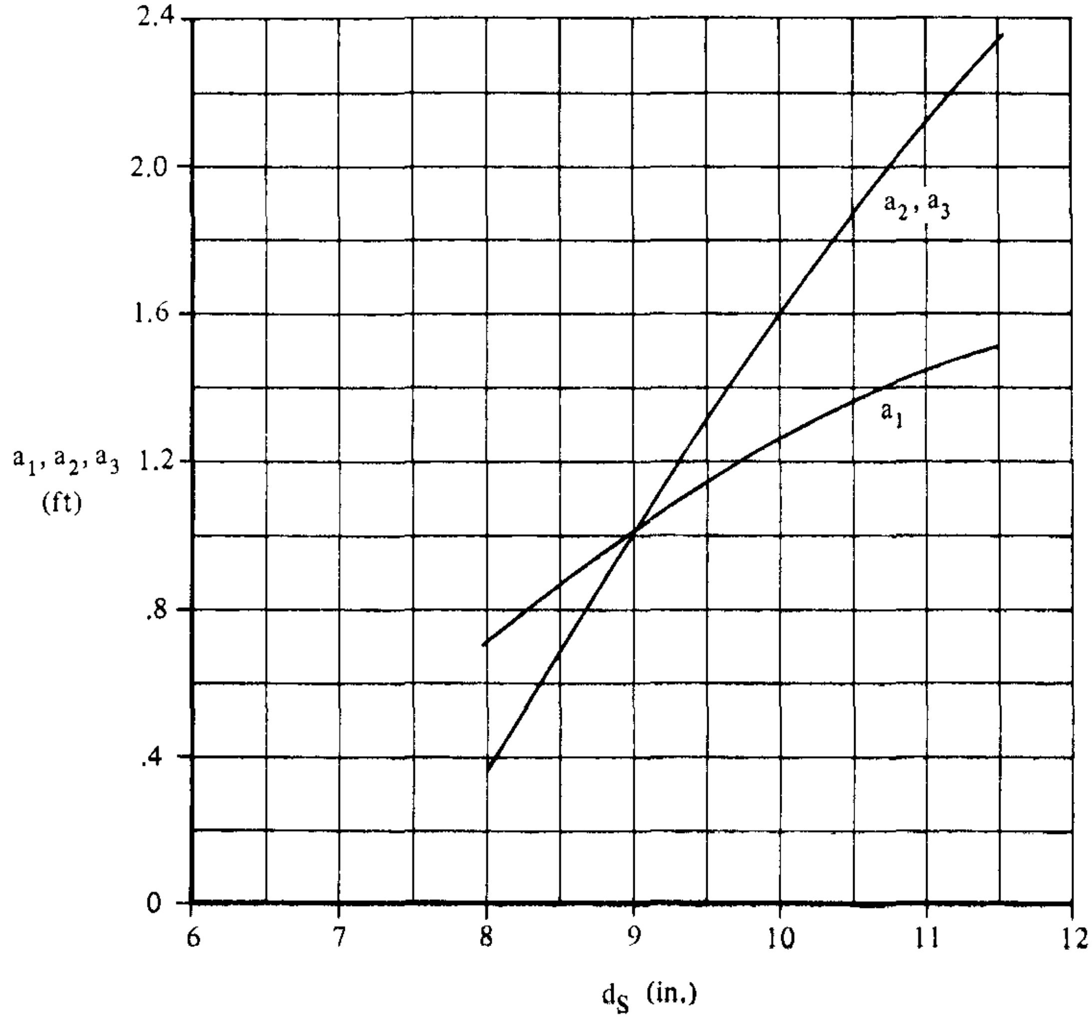


FIGURE 3.2.1.1-35 STORE-DIAMETER CORRELATION FACTORS

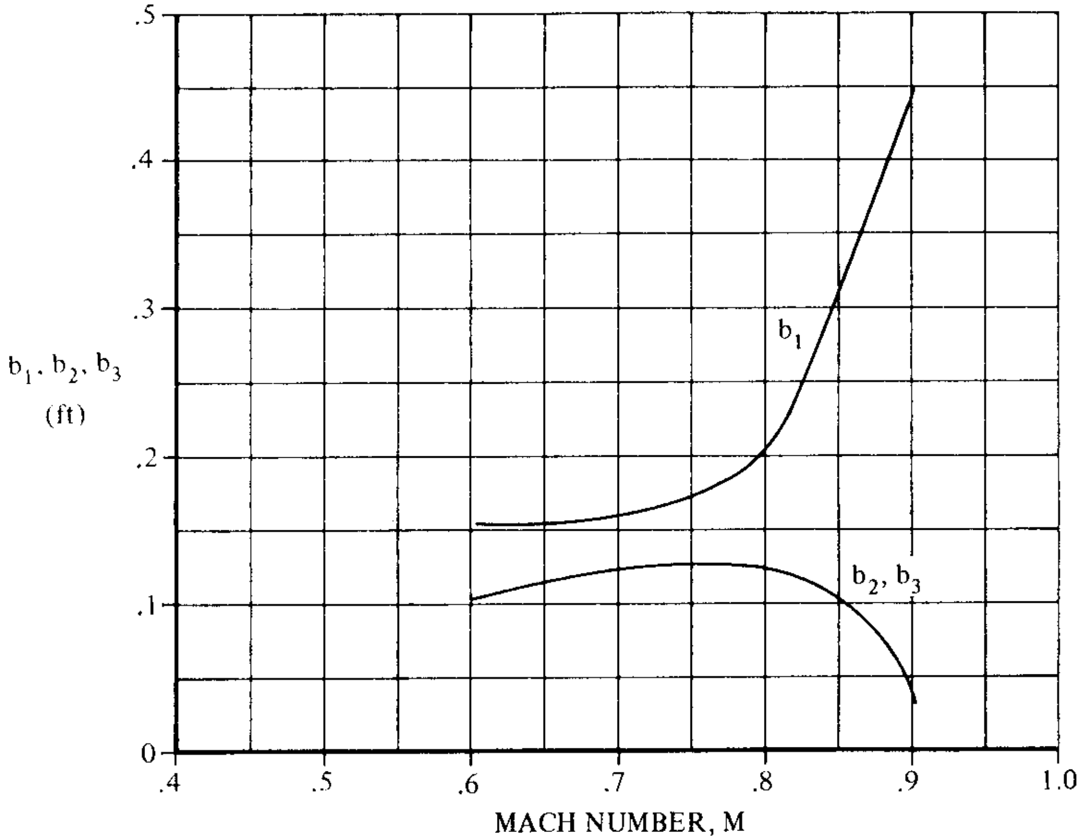


FIGURE 3.2.1.1-36 ROW MACH-CORRELATION FACTORS

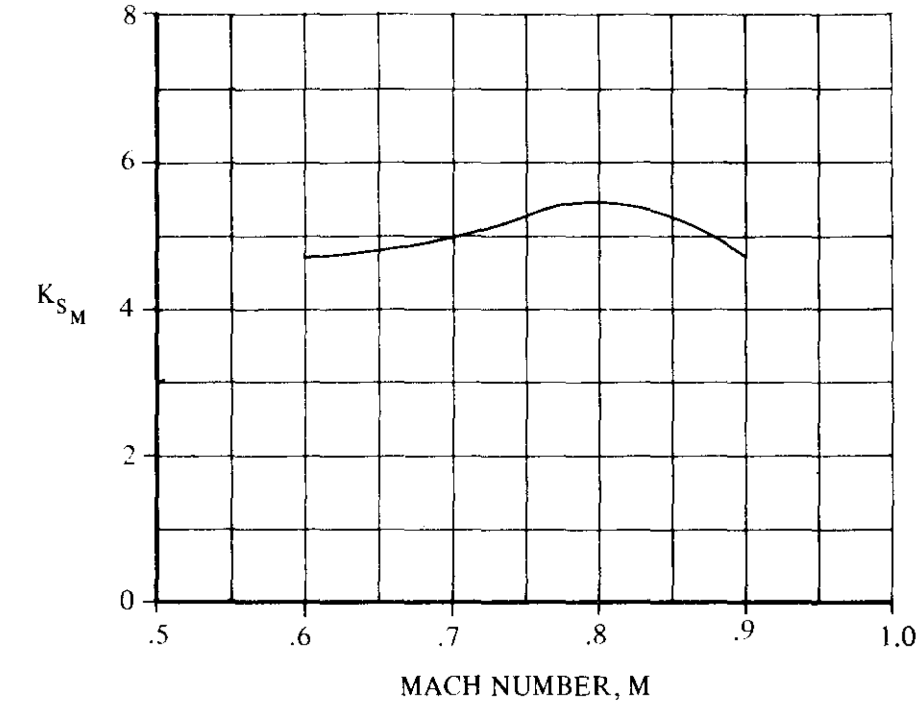


FIGURE 3.2.1.1-37a MACH EFFECT FACTOR FOR K_{D_1}

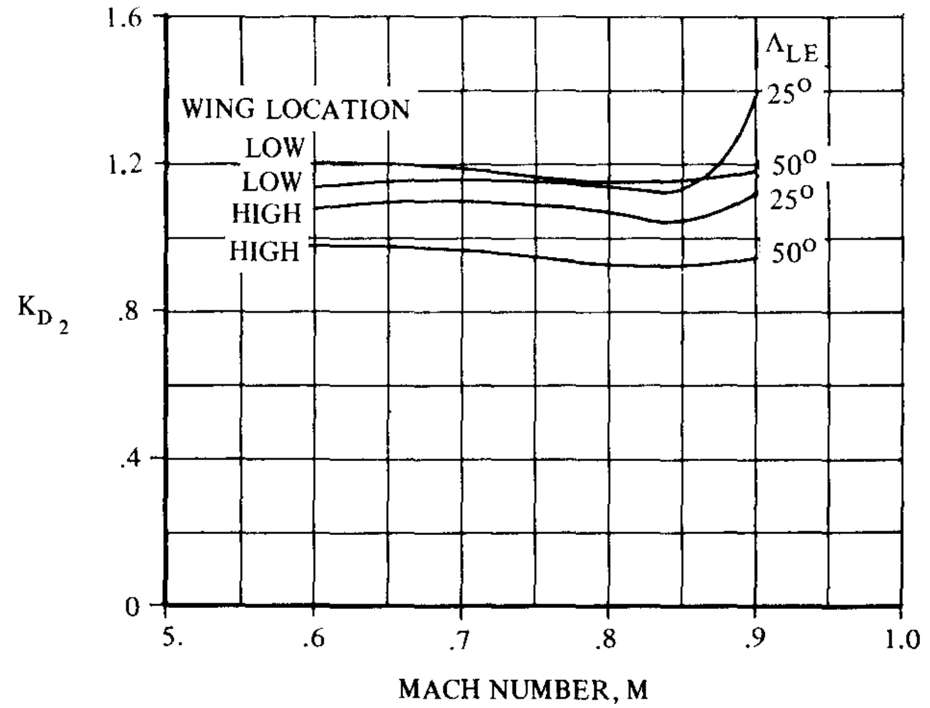


FIGURE 3.2.1.1-37b WING-SWEEP-AND-LOCATION FACTOR

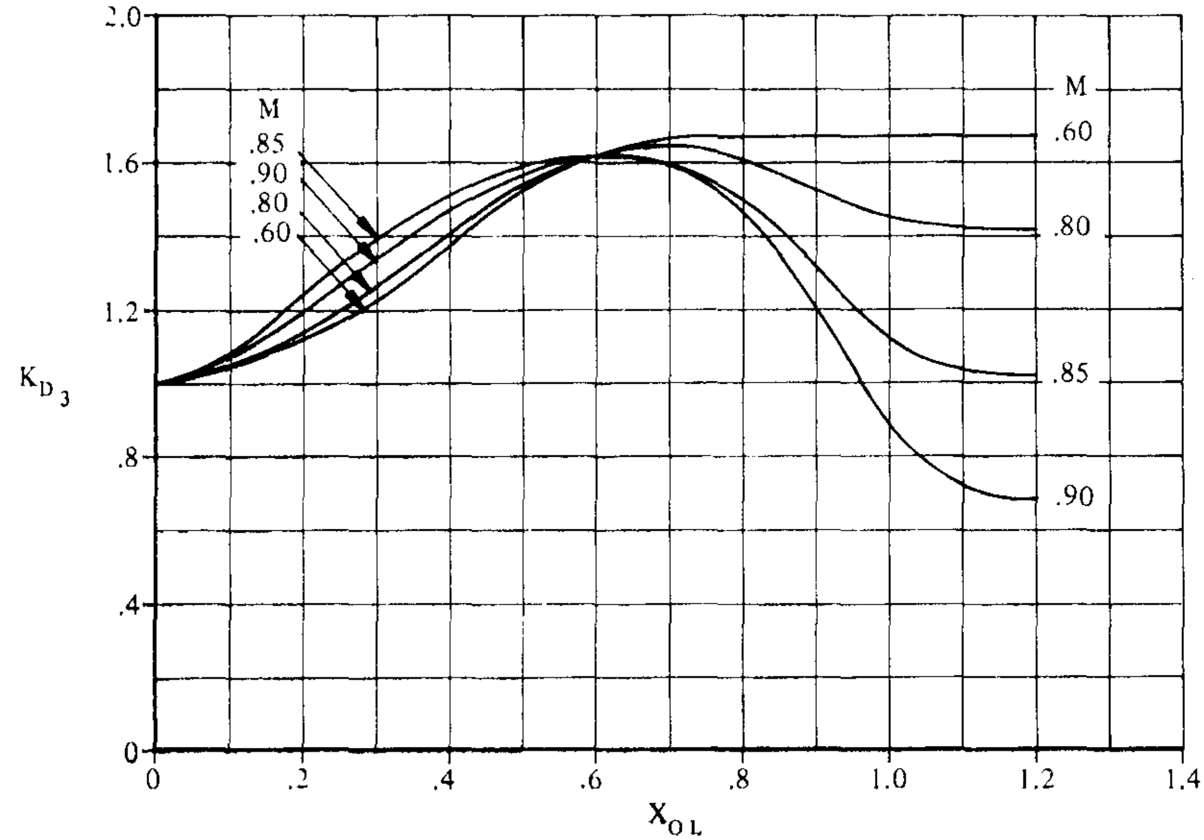


FIGURE 3.2.1.1-38a TANDEM-SPACING FACTOR

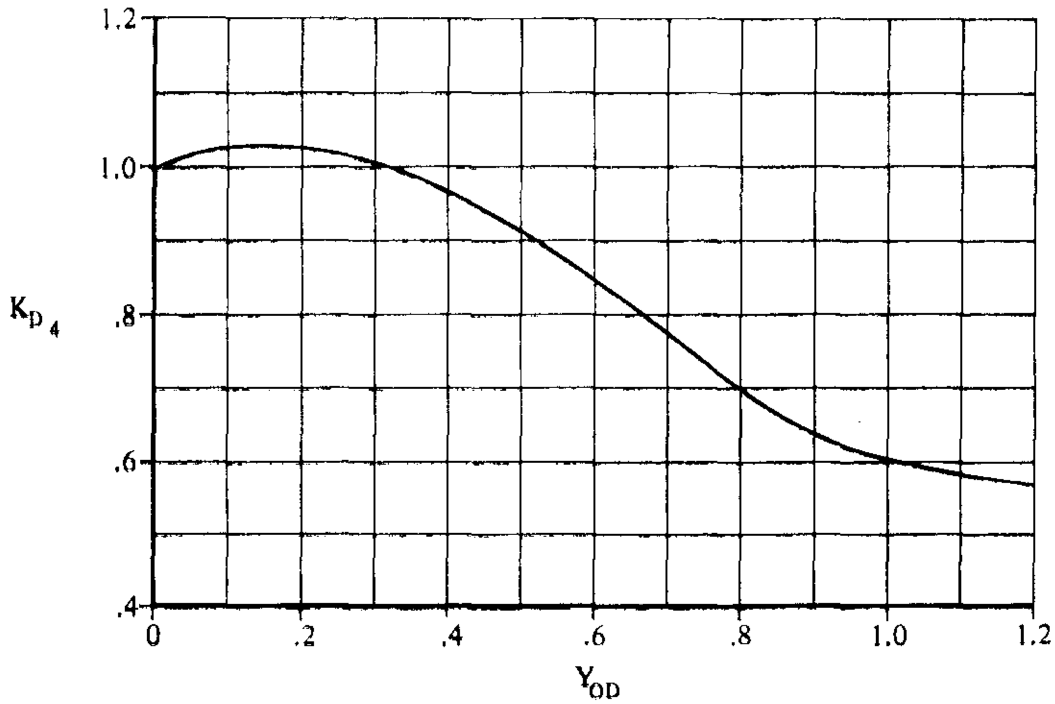


FIGURE 3.2.1.1-38b LATER-SPACING FACTOR

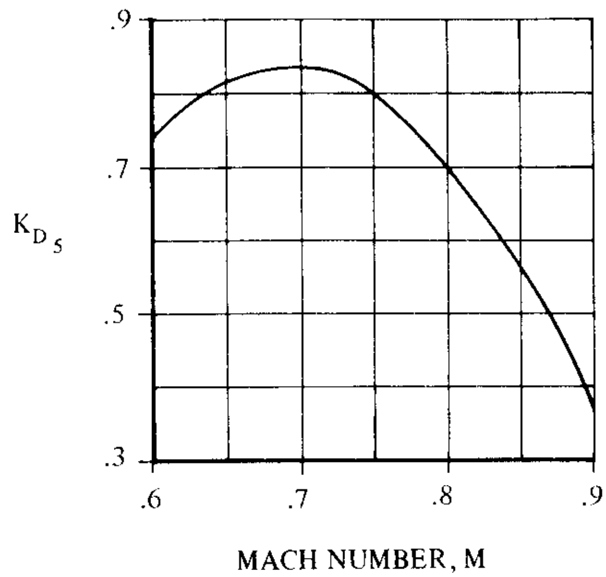


FIGURE 3.2.1.1-39a STORE-ROWS FACTOR FOR ONE ROW

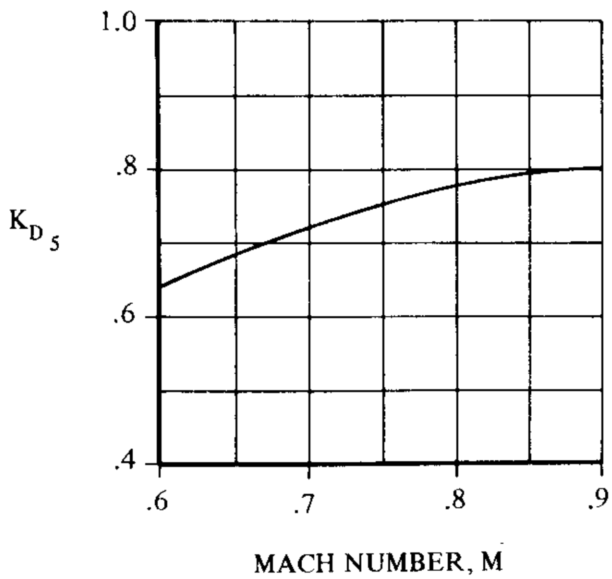


FIGURE 3.2.1.1-39b STORE-ROWS FACTOR FOR TWO ROWS

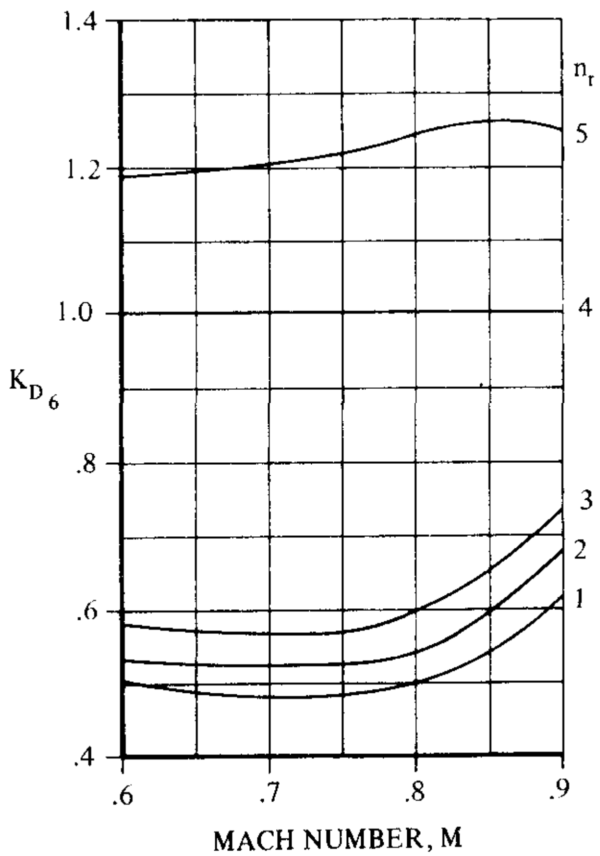


FIGURE 3.2.1.1-40 STORES-PER-ROW FACTOR FOR ONE STORE PER ROW

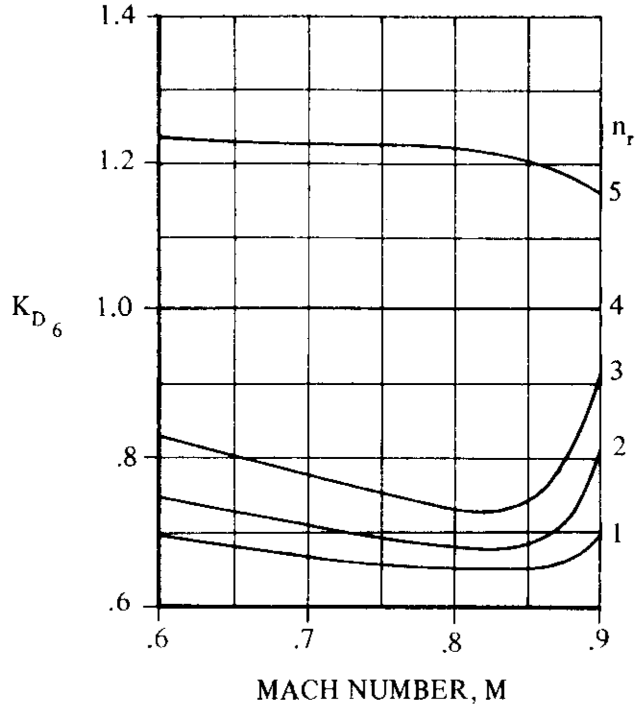


FIGURE 3.2.1.1-41a STORES-PER-ROW FACTOR FOR TWO STORES PER ROW

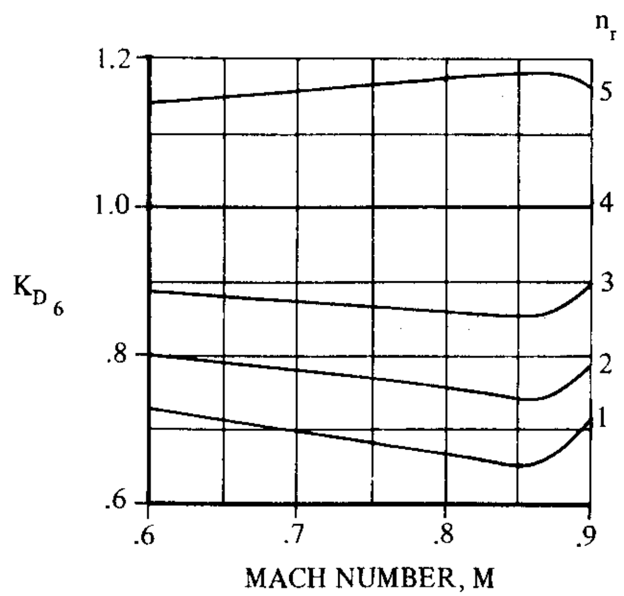


FIGURE 3.2.1.1-41b STORES-PER-ROW FACTOR FOR THREE STORES PER ROW

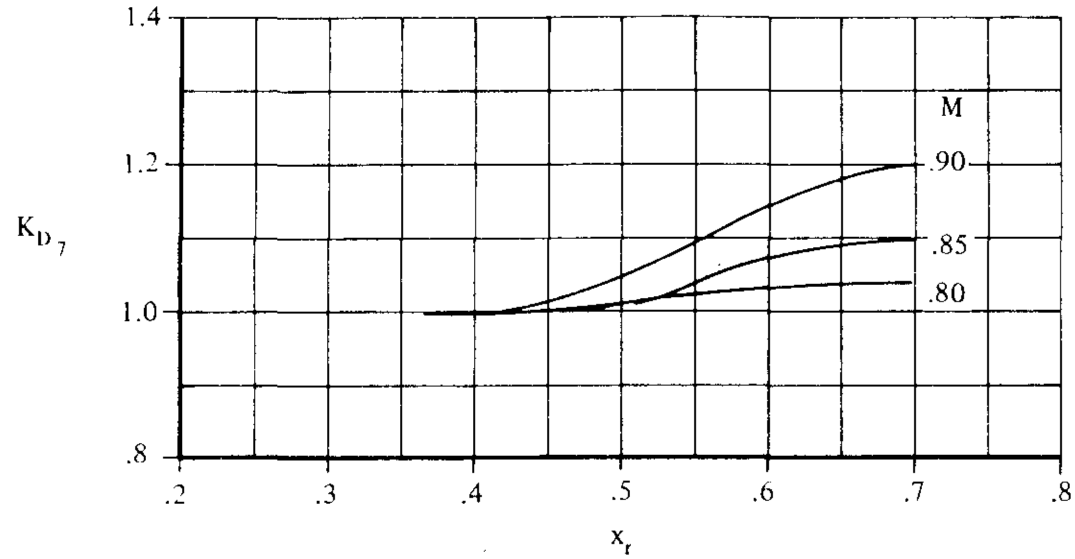


FIGURE 3.2.1.1-42a STORE-LONGITUDINAL-LOCATION FACTOR

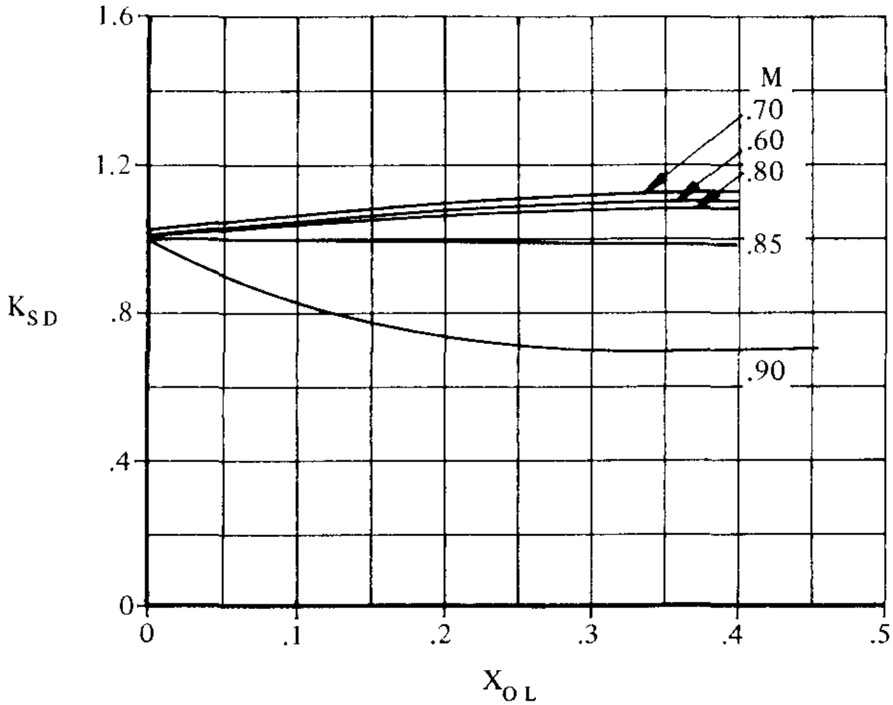
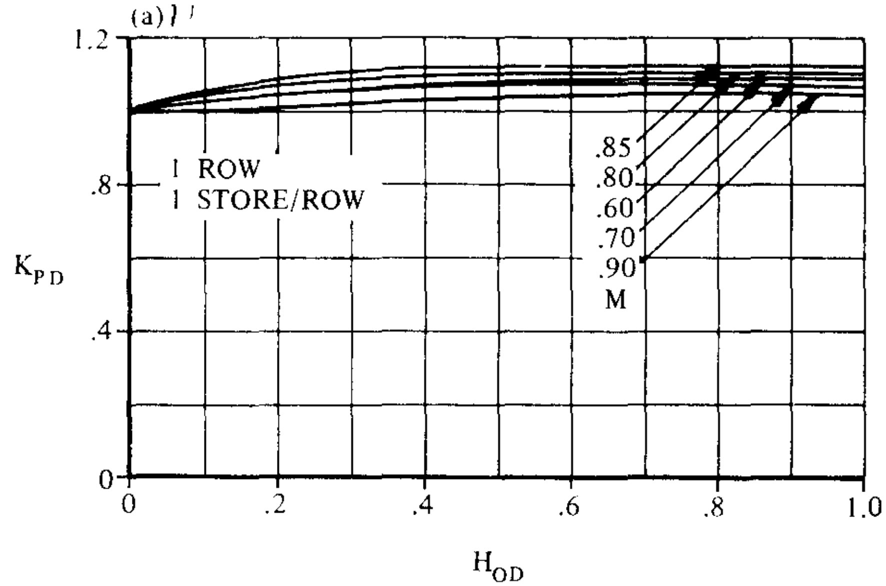
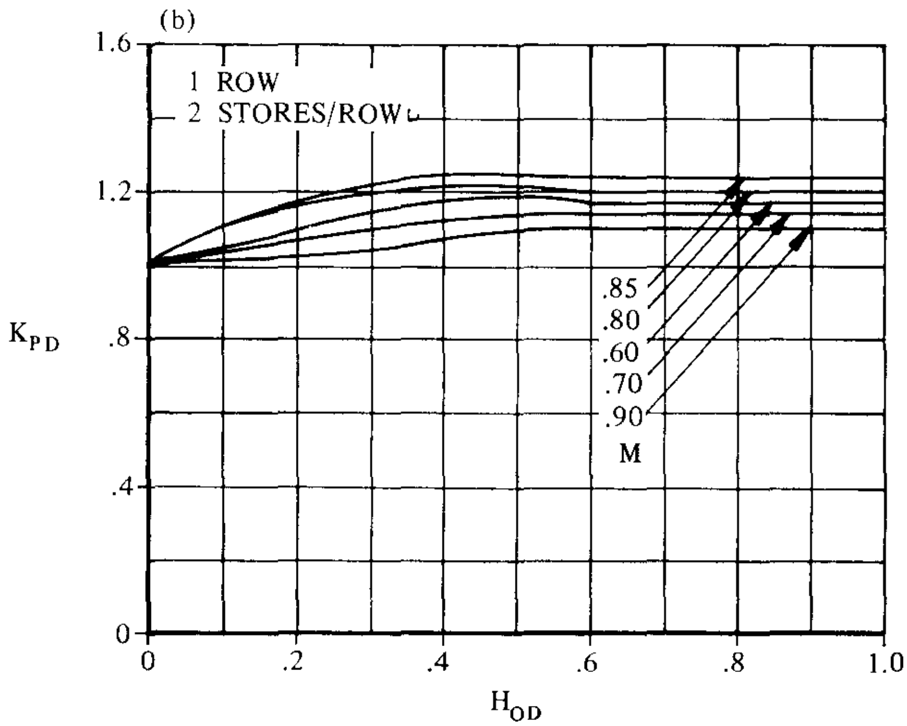
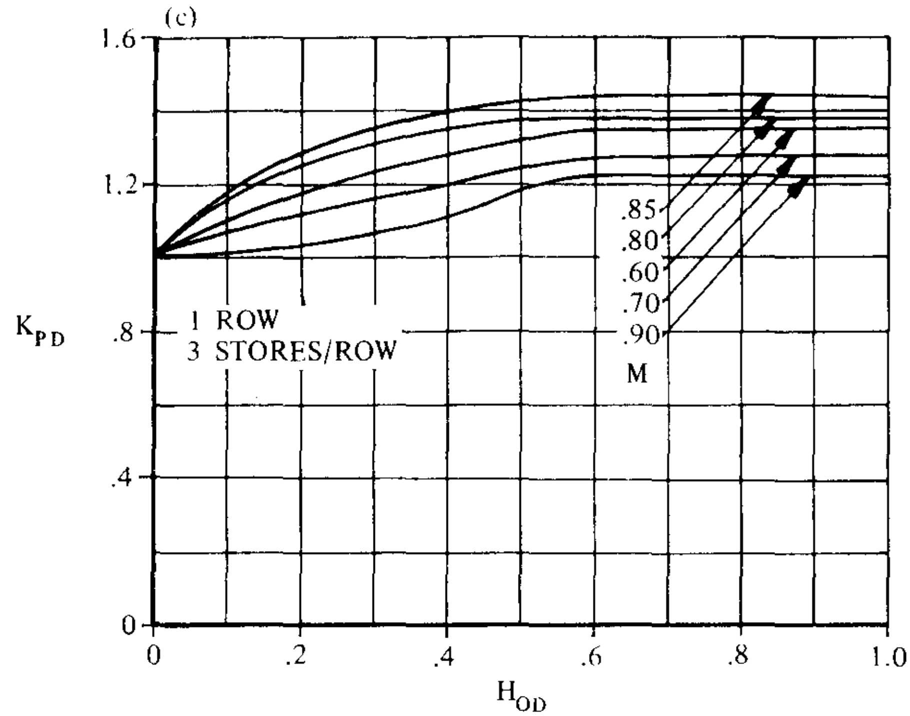


FIGURE 3.2.1.1-42b STORE-DEPTH FACTOR





STORE 3.2.1.1-43 PYLON-DEPTH FACTOR



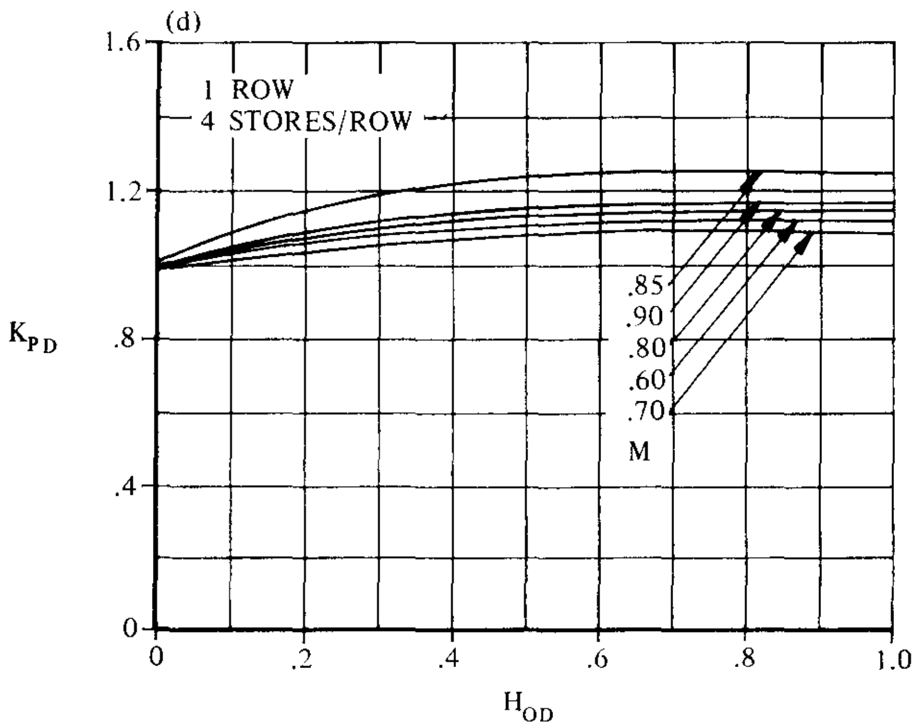
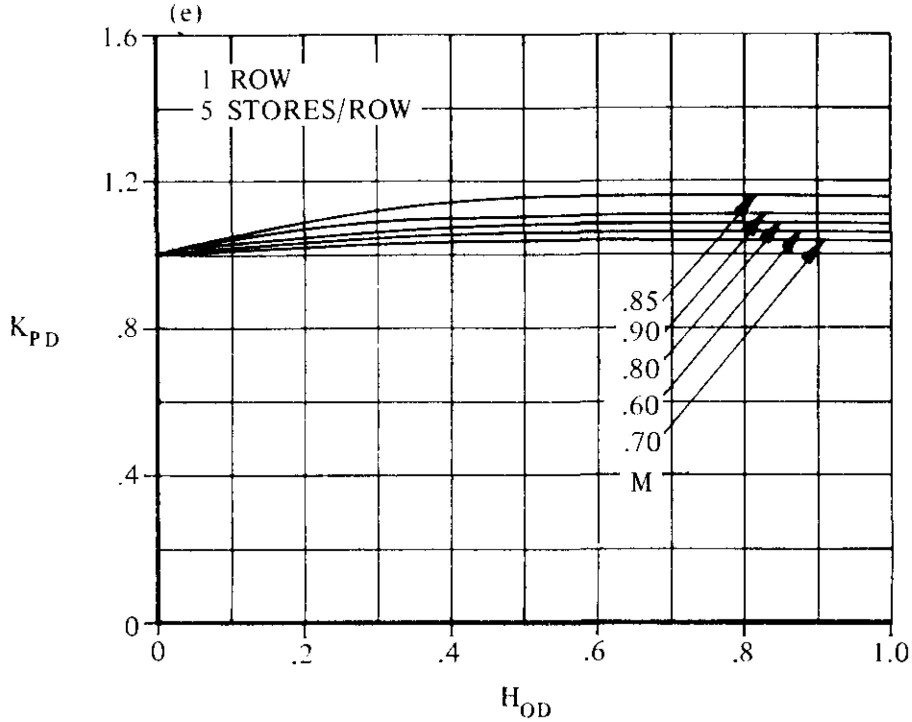


FIGURE 3.2.1.1-43 (CONTD)



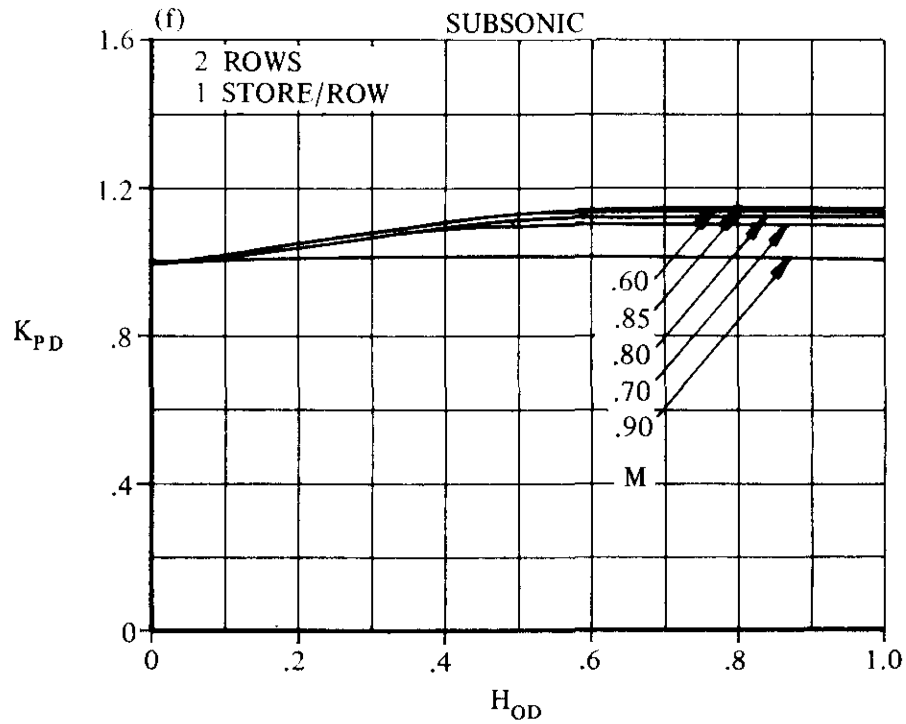
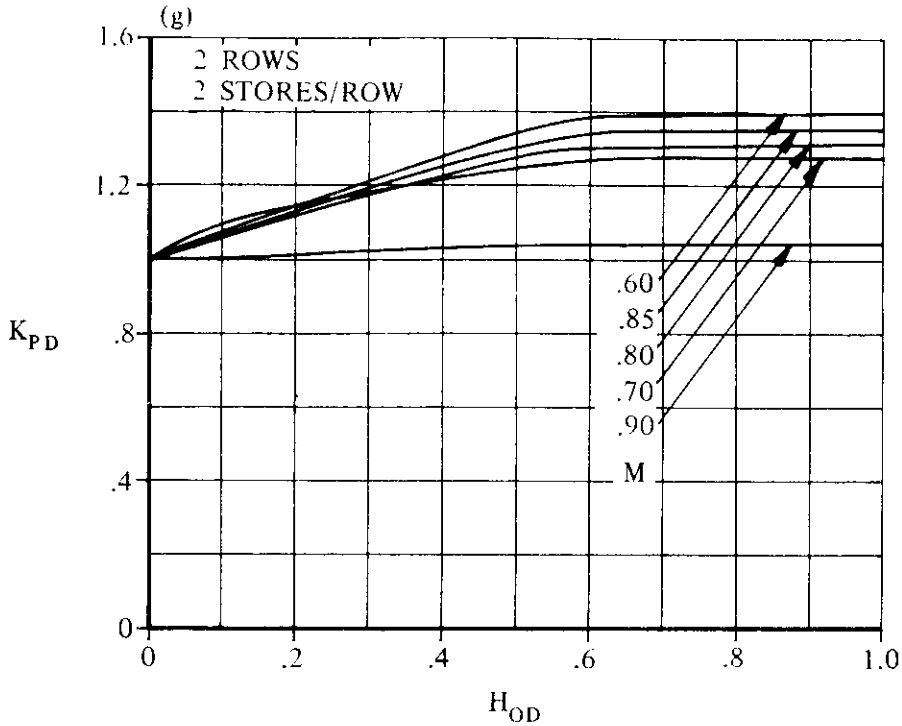


FIGURE 3.2.1.1-43 (CONTD)



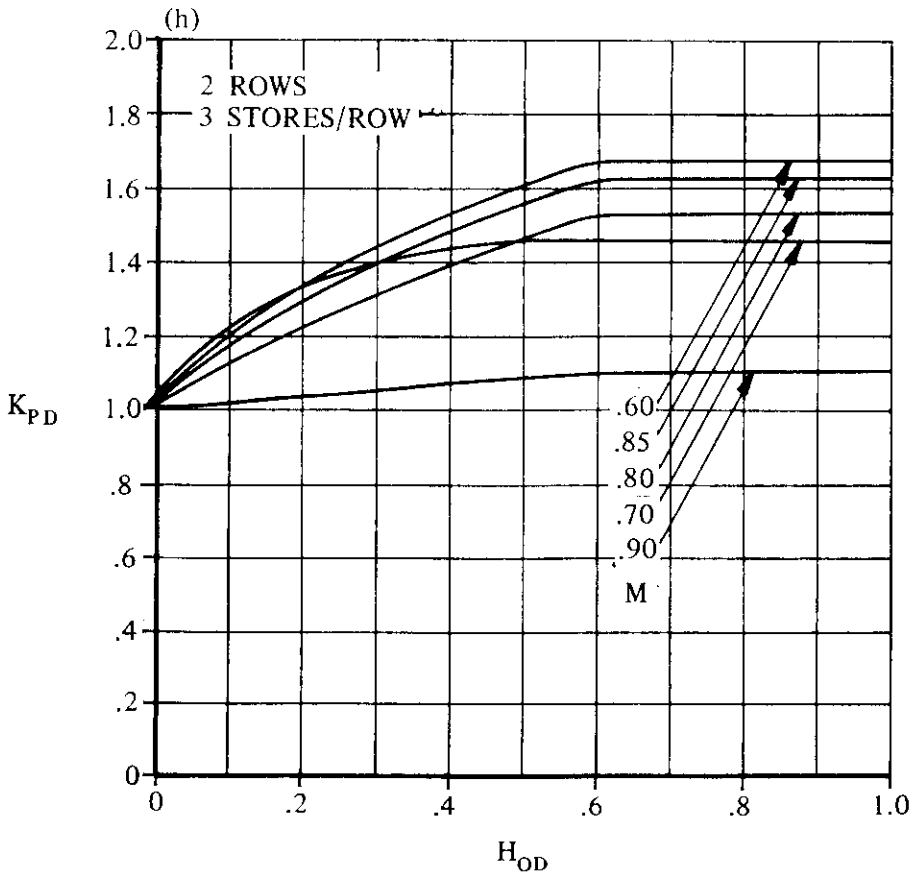


FIGURE 3.2.1.1-43 (CONTD)

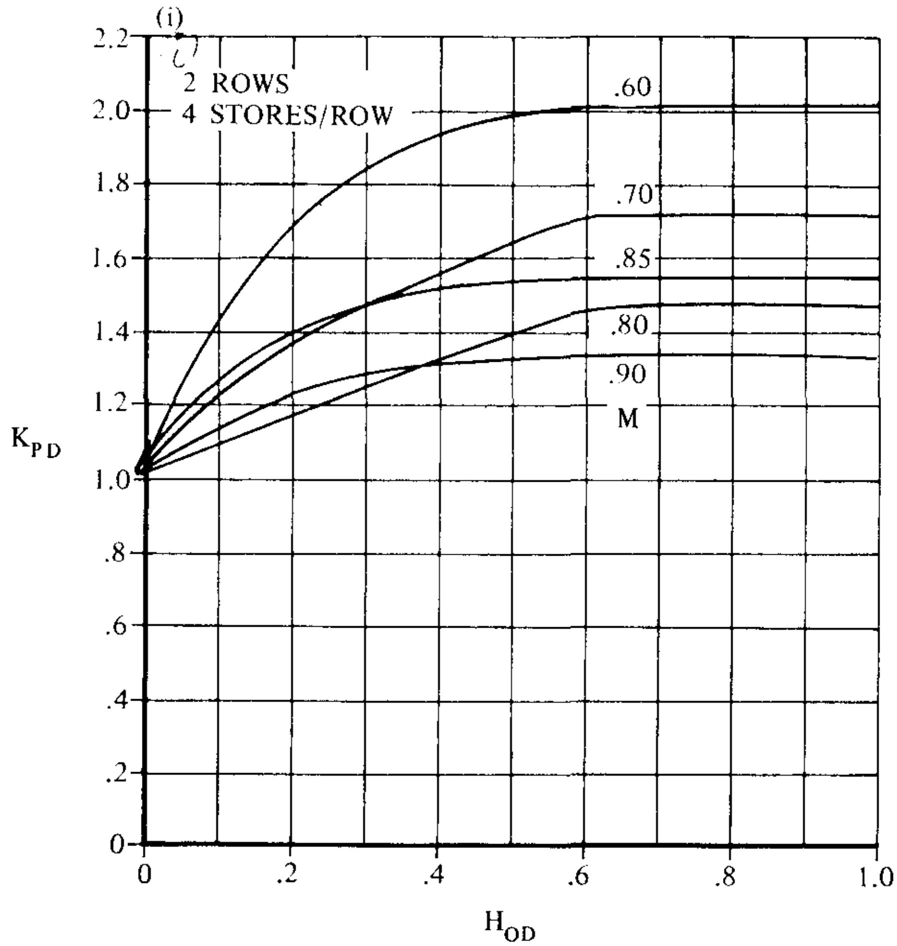
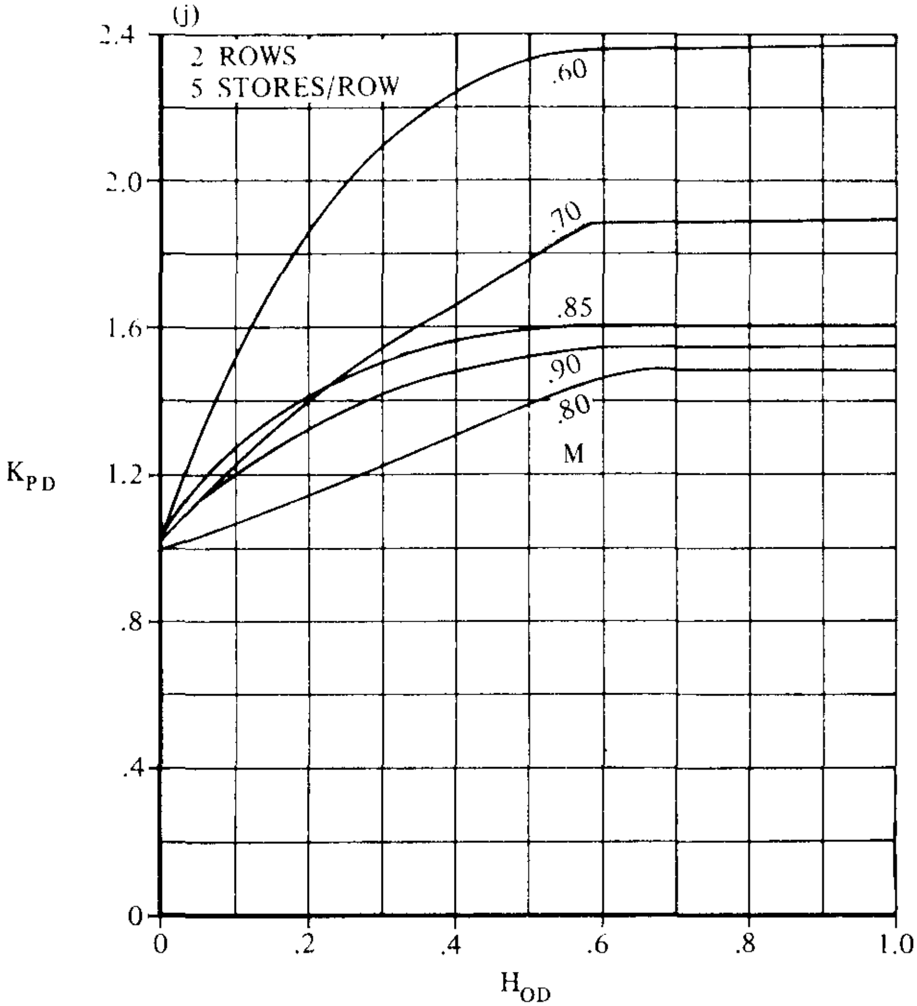


FIGURE 3.2.1.1-43 (CONTD)



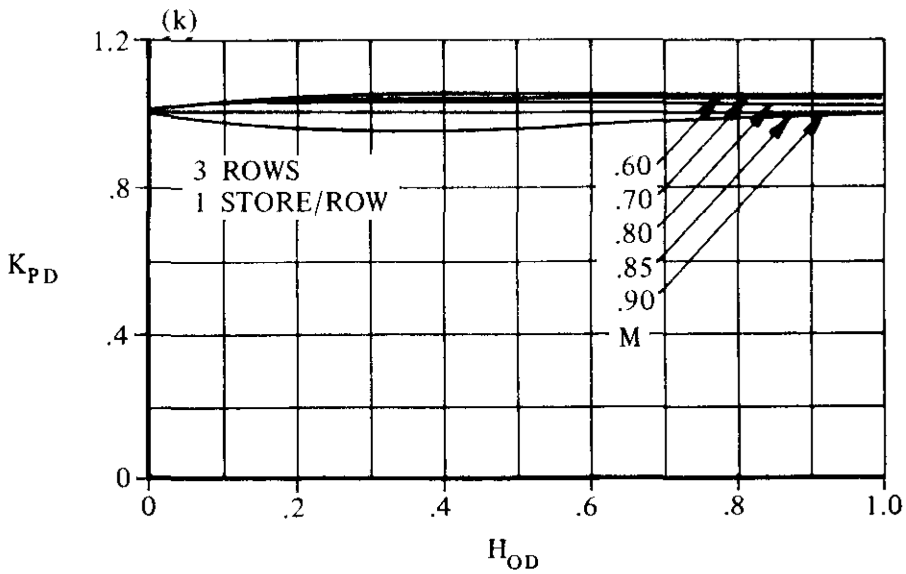
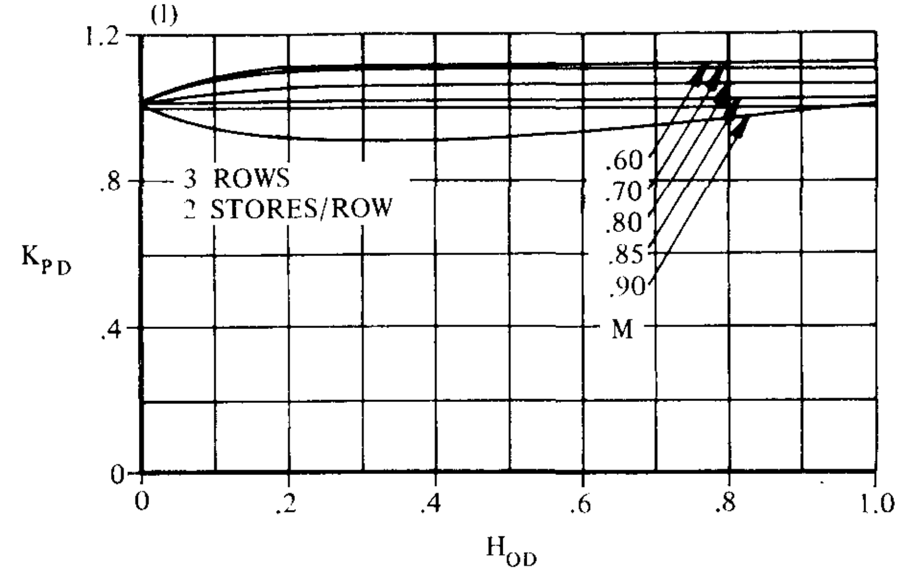


FIGURE 3.2.1.1-43 (CONTD)



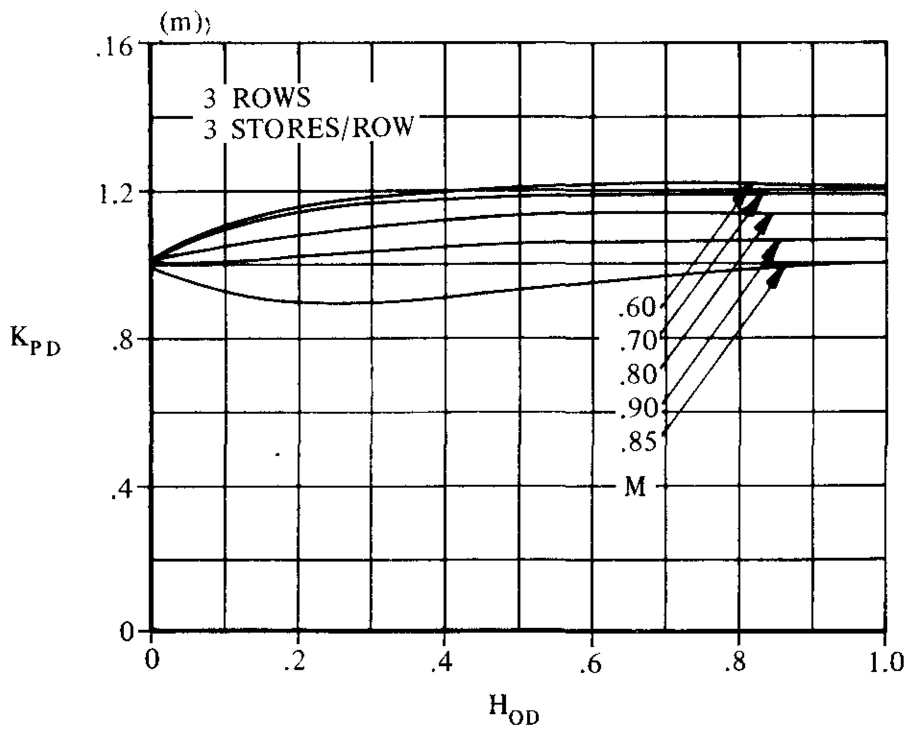
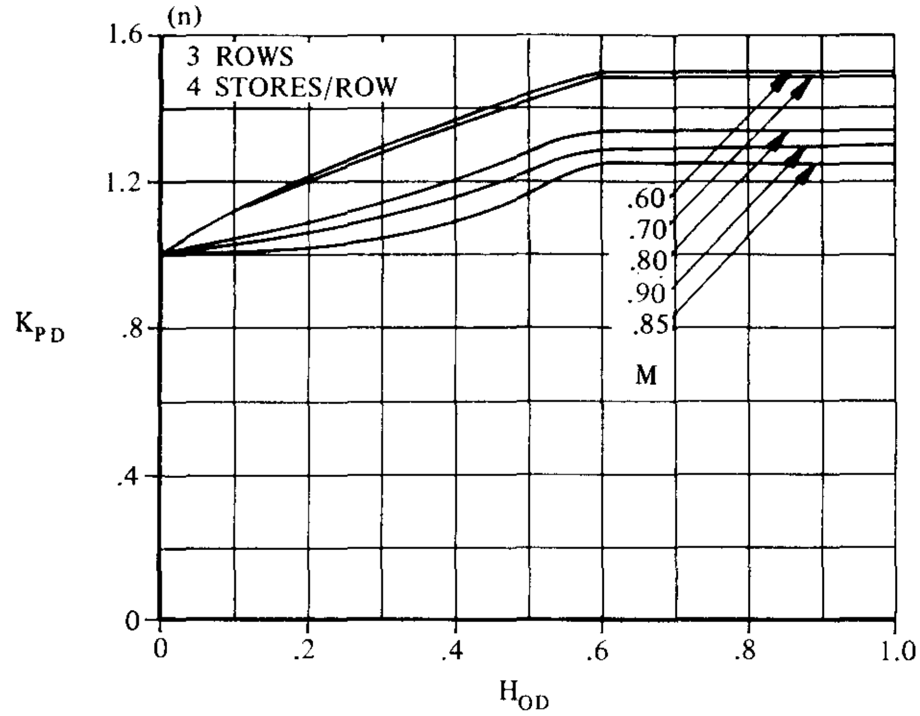


FIGURE 3.2.1.1-43 (CONTD)



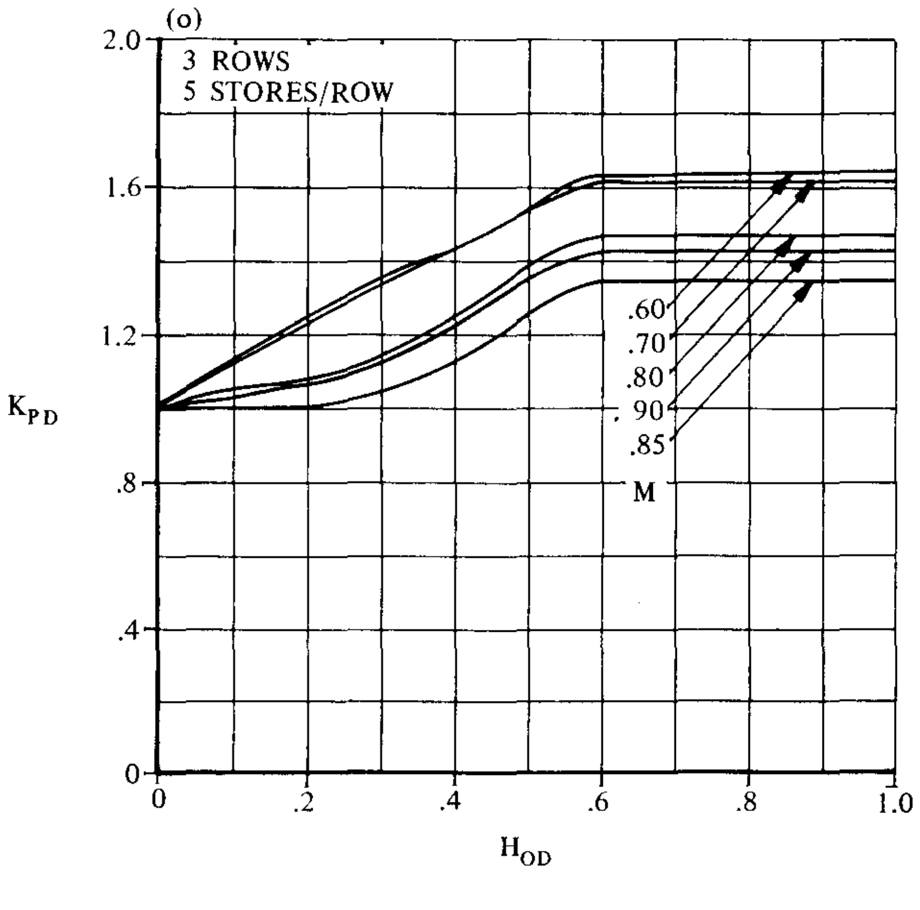
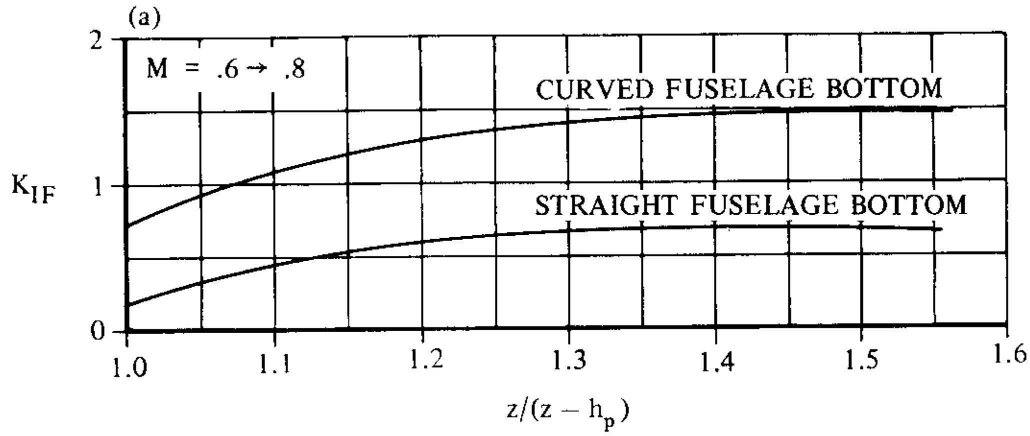


FIGURE 3.2.1.1-43 (CONTD)



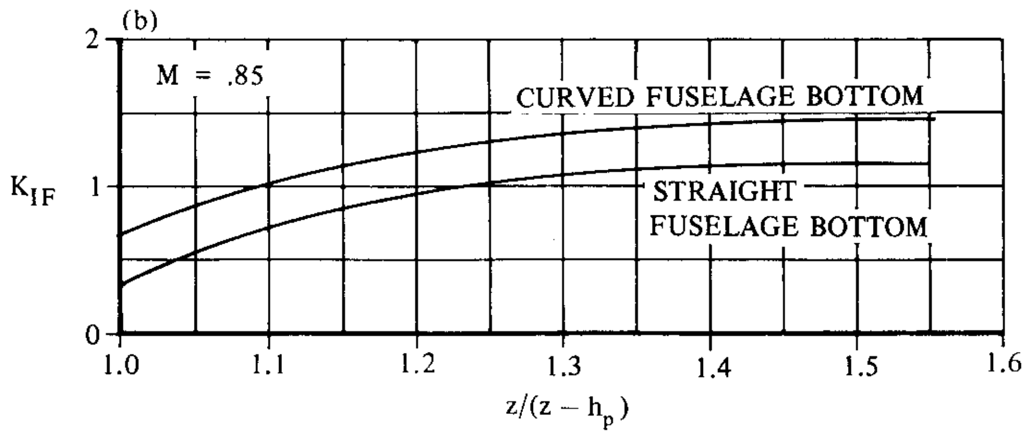
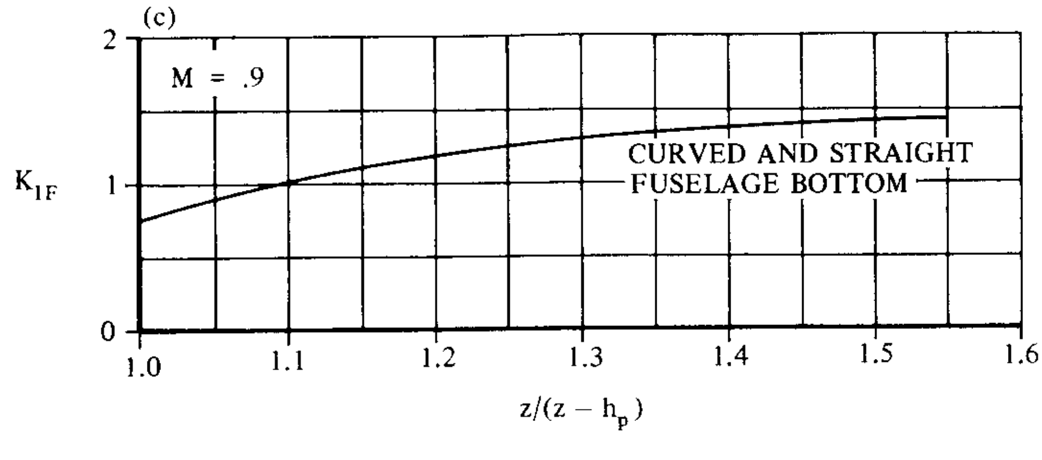


FIGURE 3.2.1.1-51 SINGLE-STORE INSTALLATION FACTOR



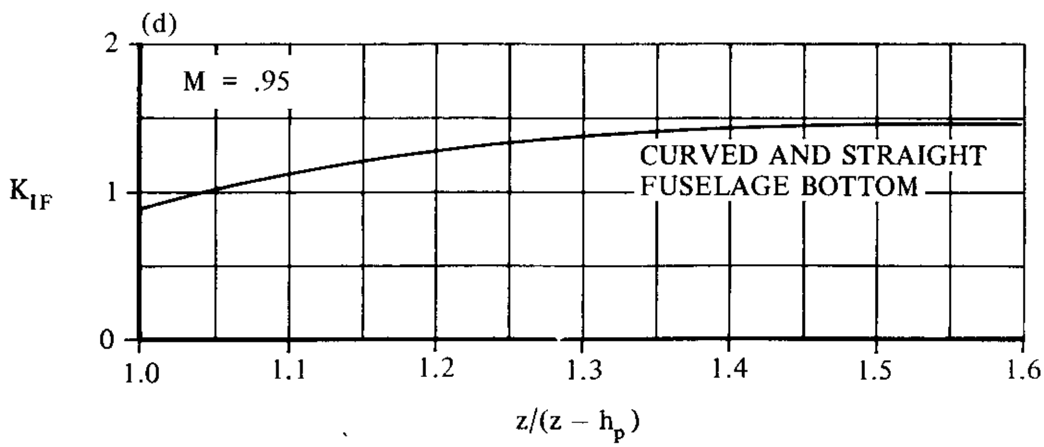


FIGURE 3.2.1.1-51 (CONTD)

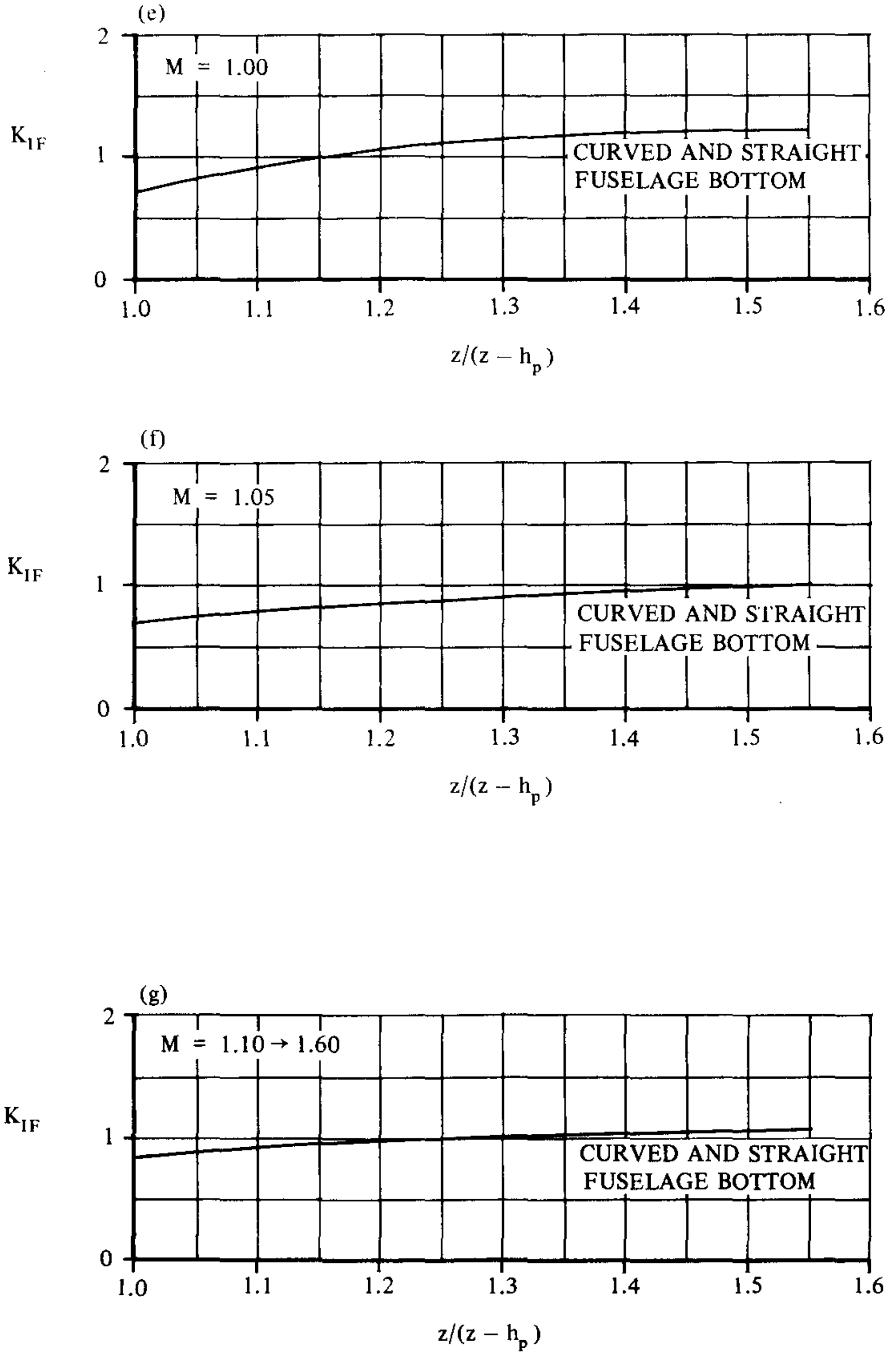
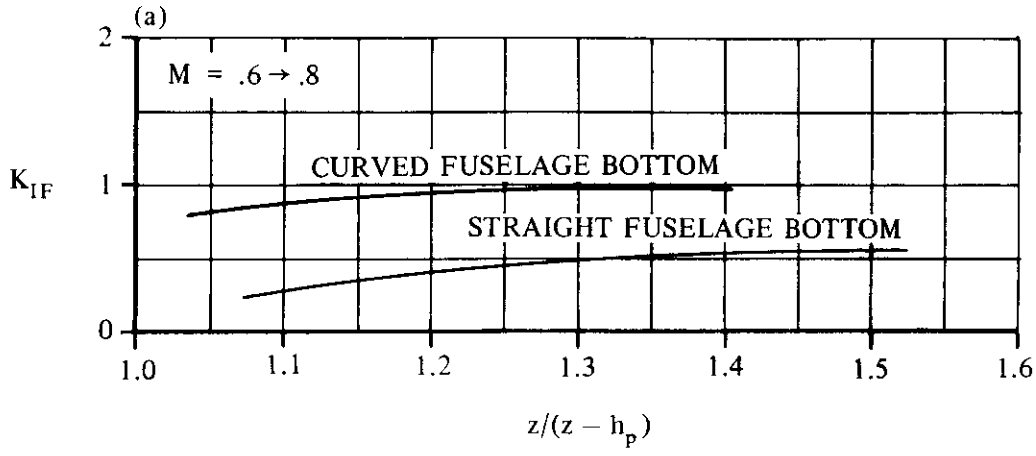


FIGURE 3.2.1.1-51 (CONTD)



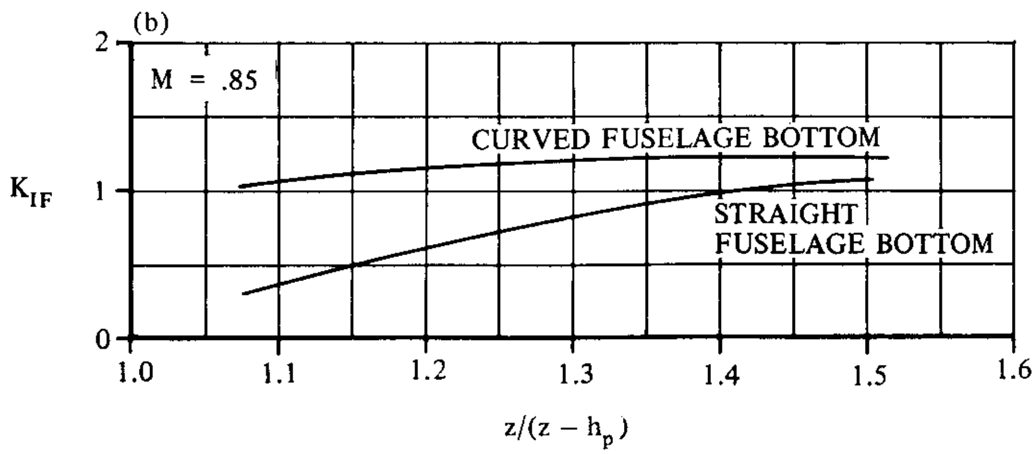
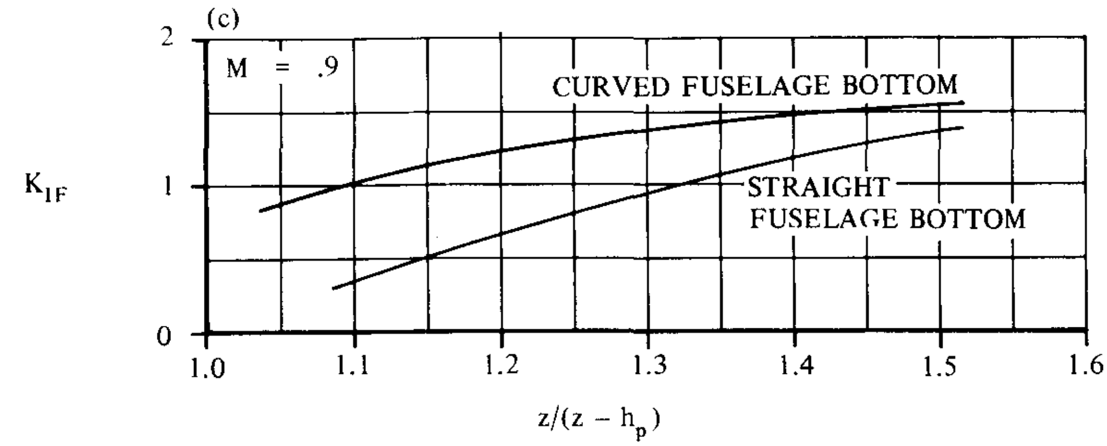


FIGURE 3.2.1.1-54 MULTIPLE-STORES INSTALLATION FACTOR



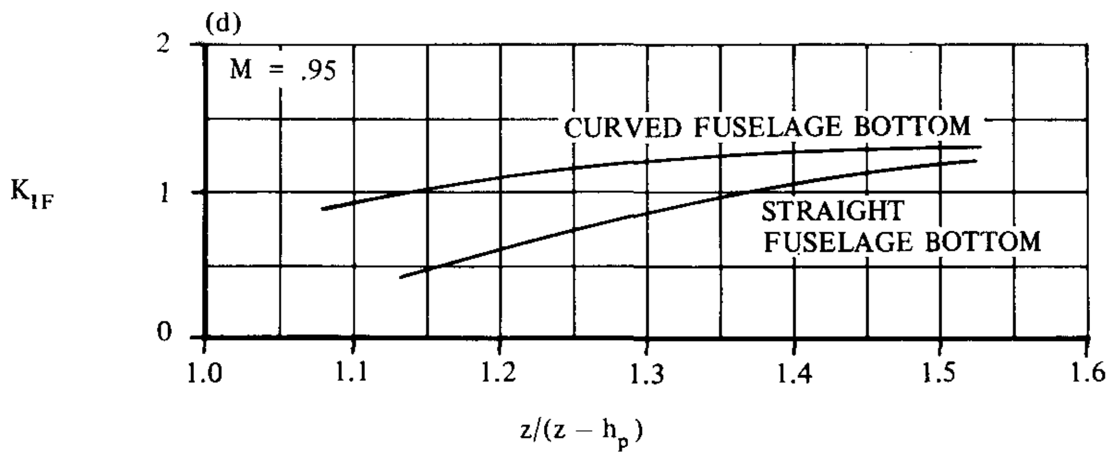


FIGURE 3.2.1.1-54 (CONTD)

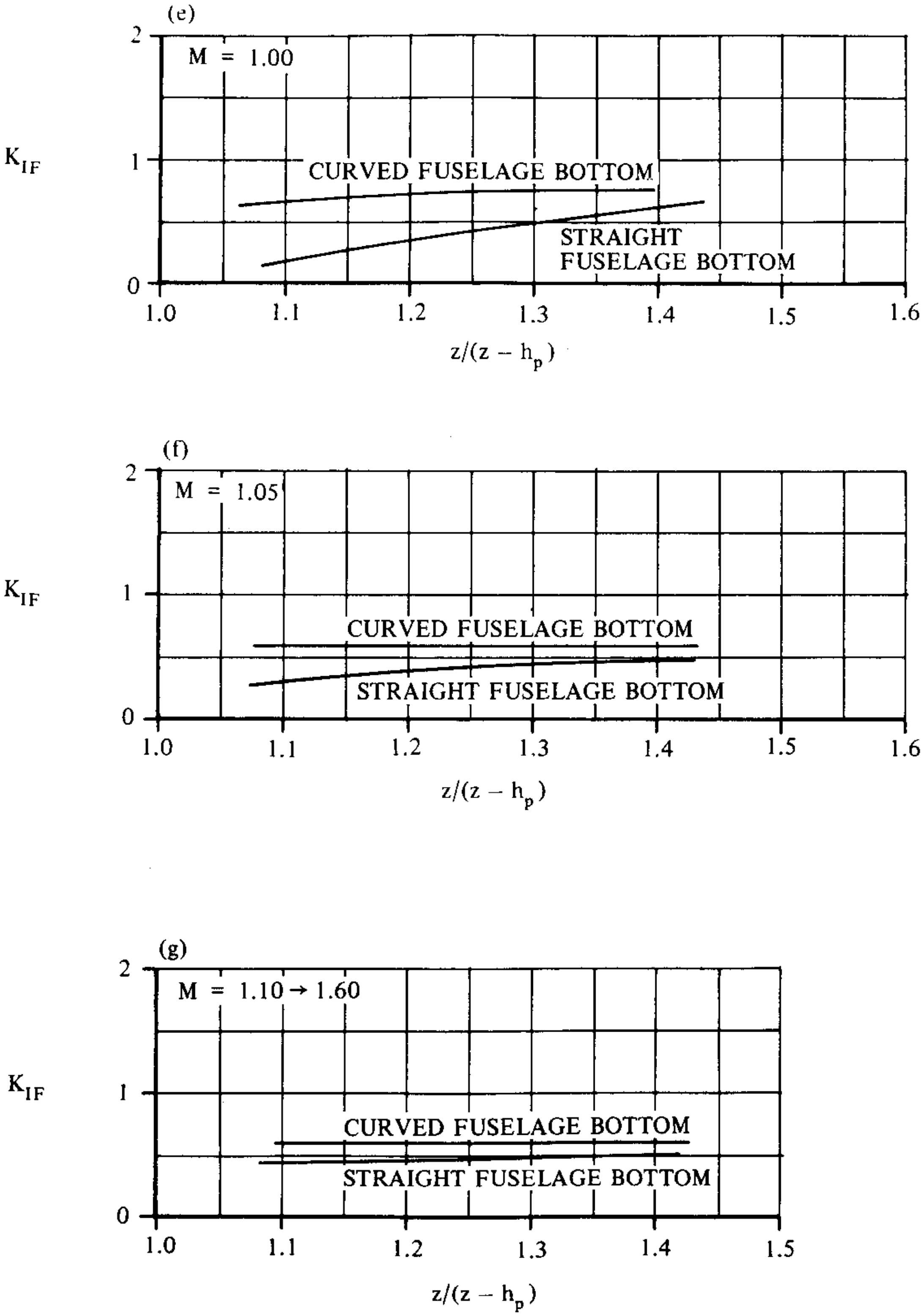


FIGURE 3.2.1.1-54 (CONTD)

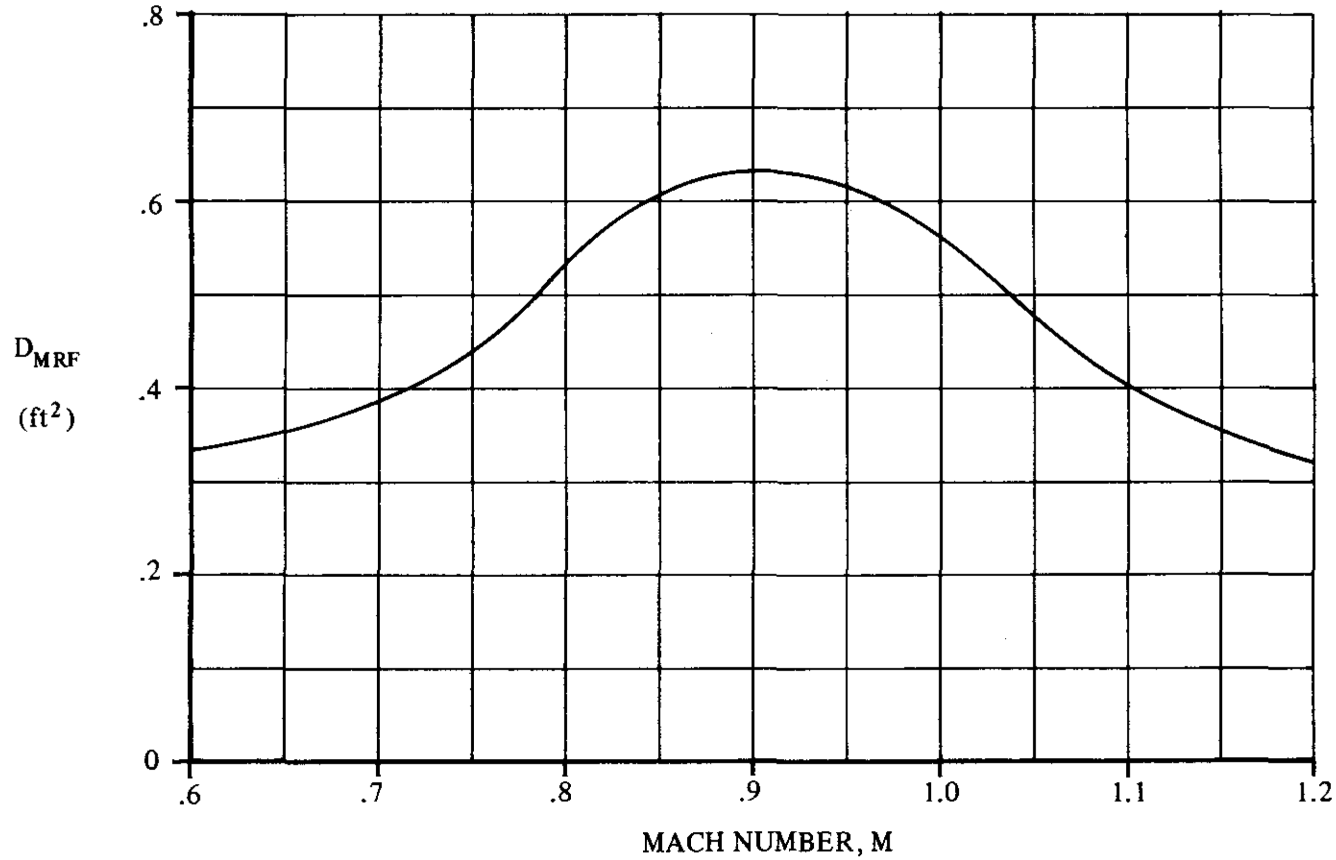


FIGURE 3.2.1.1-57 MER-RACK-TO-FUSELAGE ZERO-LIFT EQUIVALENT-PARASITE-DRAG AREA

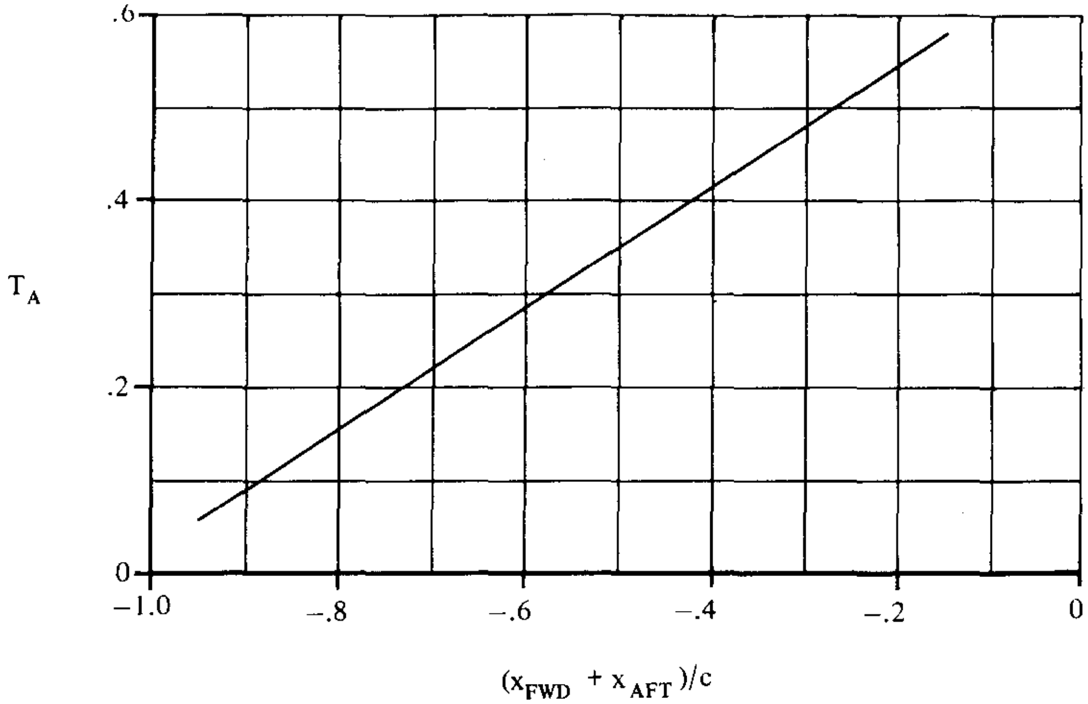


FIGURE 3.2.1.1-58a TRANSONIC-SUPERSONIC CORRELATION FACTOR

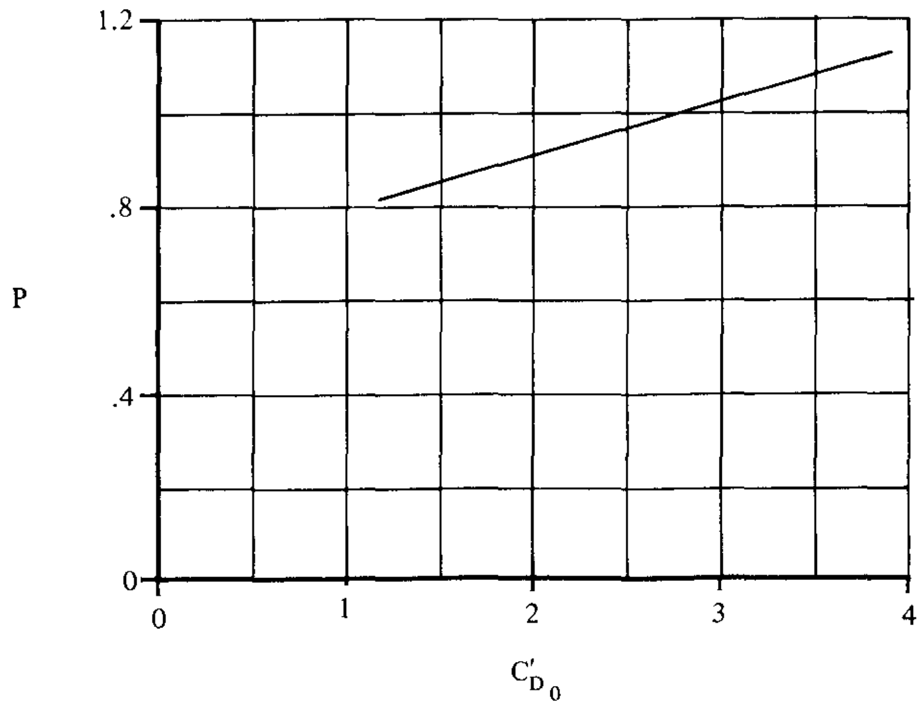


FIGURE 3.2.1.1-58b CLEAN AIRCRAFT DRAG-RISE FACTOR

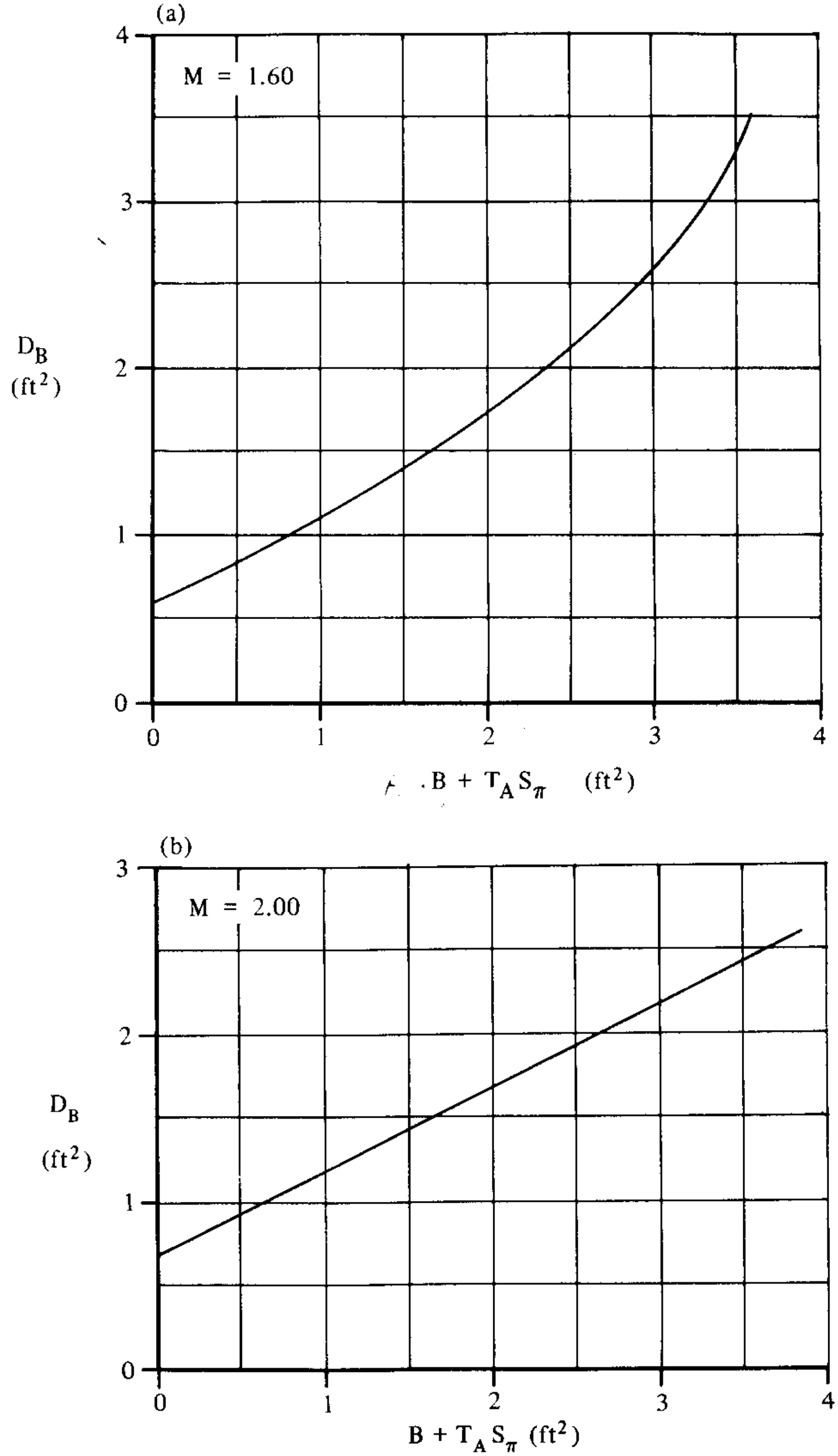
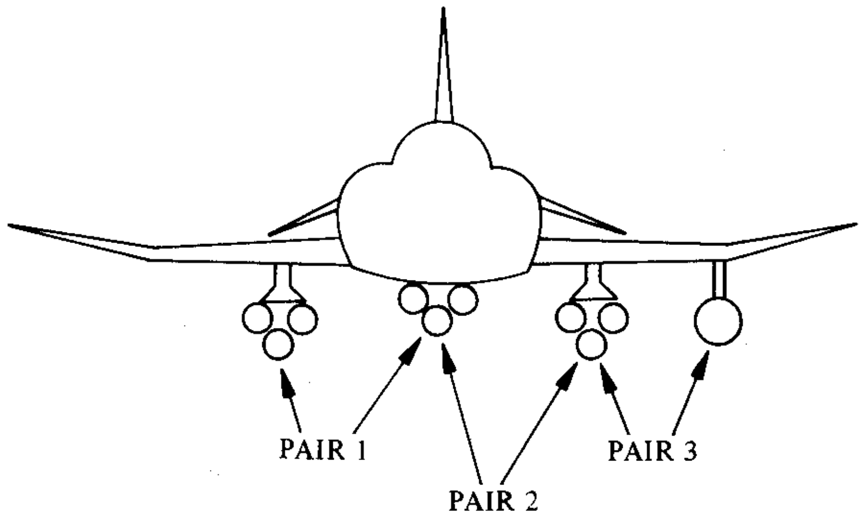


FIGURE 3.2.1.1-59 ZERO-LIFT EQUIVALENT-PARASITE-DRAG AREA FOR A WING-PYLON-MOUNTED SINGLE STORE

3.2.1.2 DRAG DUE TO ADJACENT STORE INTERFERENCE

A method is presented in this section for estimating the zero-lift equivalent-parasite-drag area due to the interference effects of a pair of adjacent store installations. When separate installations are mounted sufficiently close to each other, an interference effect on drag is produced which should be accounted for in the total drag estimate. This effect may be either positive or negative, depending upon the relative positions of the store installations. The effect is computed for each pair of adjacent installations on the aircraft. For example, the aircraft pictured in Sketch (a) would require three computations.



SKETCH (a)

The Datcom Method is taken from Reference 1 and is empirical in nature. The method is applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The limitations on configuration and Mach-number range are summarized in Table 3.2-A. Caution should be used when extrapolating the curves beyond the given Mach-number range. The method has not been verified for configurations in which flaps, slats, or other flow-disrupting devices are deployed.

A. SUBSONIC

DATCOM METHOD

The zero-lift equivalent-parasite-drag area (ft^2) due to the mutual interference of adjacent store installations per pair of adjacent store installations is given by D_{I_S} where

D_{I_S} is obtained from Figures 3.2.1.2-4a through -4c as a function of Mach number, Y_S, d_{w_L}, d_{w_A}, T_N, and ℓ_{AFT}.

where these terms are illustrated in Sketch (b) and defined as

Y_S is the minimum lateral clearance (in.) between adjacent-store installations (store surface to store surface).

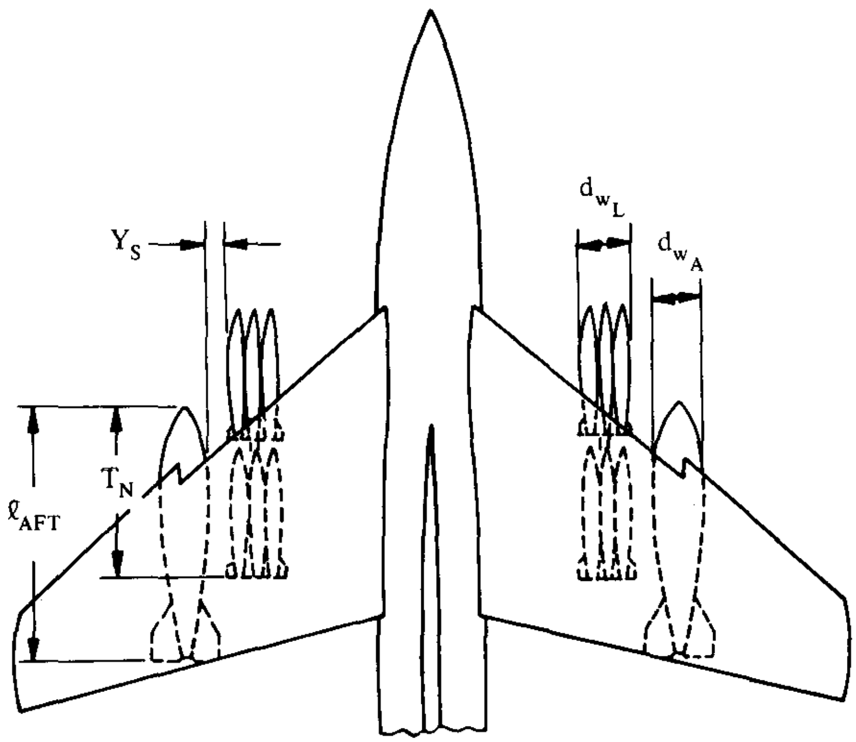
d_{w_L} is the maximum width (in.) of the lead- (most forward) store installation.

d_{w_A} is the maximum width (in.) of the aft-store installation.

T_N is the distance from the nose of the aft-store installation to the tail of the lead-store installation (in.)

ℓ_{AFT} is the length (in.) of the aft-store installation.

It is necessary to use interpolation for Mach numbers not presented in the figures.



SKETCH (b)

Sample Problem

Given: A swept-wing aircraft symmetrically loaded as shown in Sketch (b).

Stores Data:

$Y_S = 10$ in. $d_{w_L} = 42$ in. $d_{w_A} = 40$ in. $T_N = 135$ in. $\ell_{AFT} = 205$ in.

Additional Data:

$M = 0.7$

Compute: Referring to Figures 3.2.1.2-4a through -4c, it can be seen that data are presented for $M = 0.6$, 0.9, and 1.2. It will, therefore, be necessary to obtain D_{I_S} at each of the three Mach numbers and interpolate to obtain the value at $M = 0.7$.

Compute the independent variables for Figures 3.2.1.2-4a through -4c:

$$\frac{Y_S}{d_{w_L} + d_{w_A}} = \frac{10}{42 + 40} = 0.122$$

$$\frac{T_N}{\ell_{AFT}} = \frac{135}{205} = 0.659$$

Solution:

At $M = 0.6$	$D_{I_S} = 0.075\ ft^2$	(Figure 3.2.1.2-4a)
At $M = 0.9$	$D_{I_S} = 0.460\ ft^2$	(Figure 3.2.1.2-4b)
At $M = 1.2$	$D_{I_S} = 0.265\ ft^2$	(Figure 3.2.1.2-4c)

Interpolating the above three points at $M = 0.7$ yields $D_{I_S} = 0.230\ ft^2$

B. TRANSONIC

The method presented in Paragraph A of this section is also applicable in the transonic speed range.

C. SUPERSONIC

The method presented in Paragraph A of this section is also applicable in the supersonic speed range. Although no design curves are presented beyond $M = 1.2$, the existing curves can be cross plotted and extrapolated to $M = 1.6$ with reasonable success.

REFERENCE

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

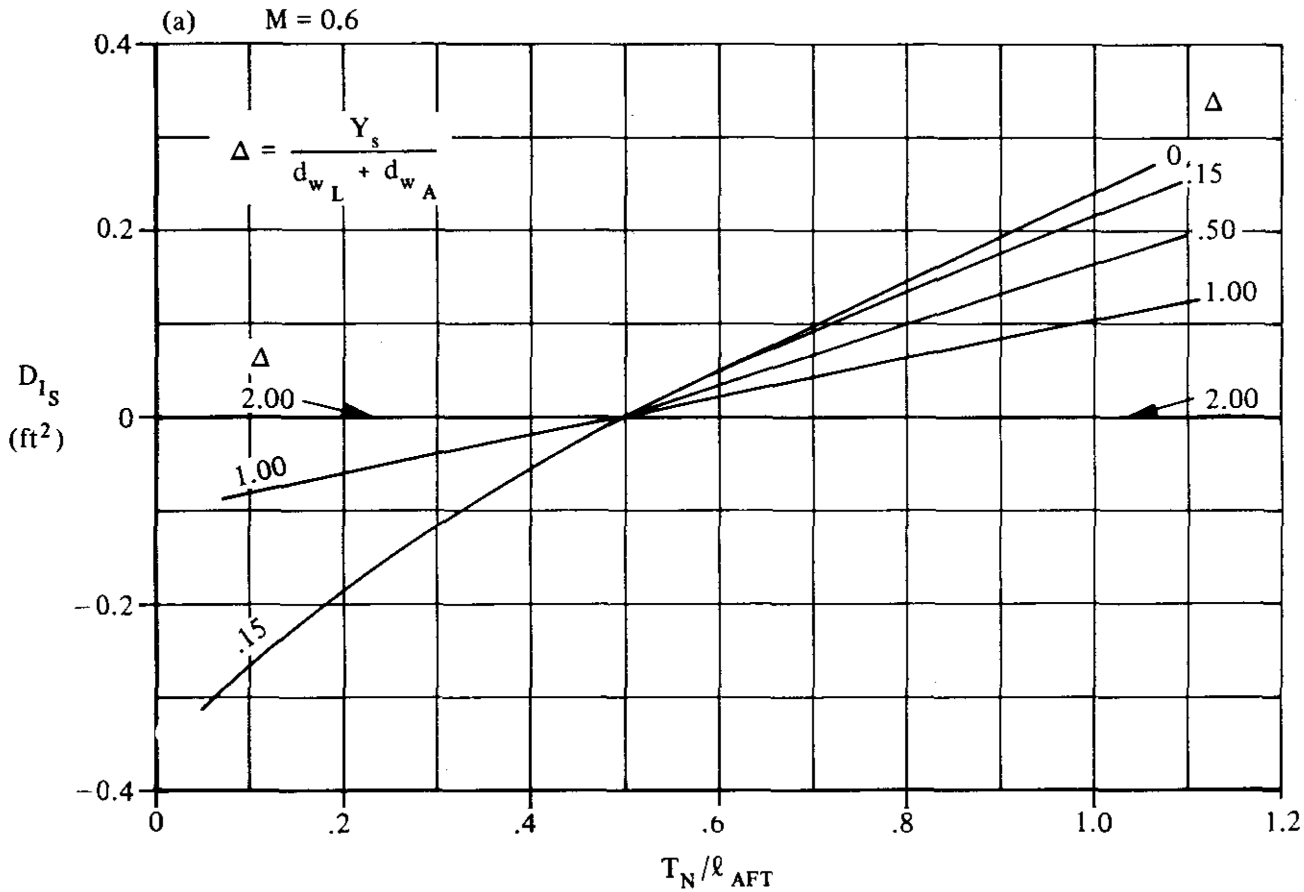


FIGURE 3.2.1.2-4 ZERO-LIFT EQUIVALENT-PARASITE-DRAG AREA DUE TO MUTUAL INTERFERENCE OF ADJACENT STORE INSTALLATIONS

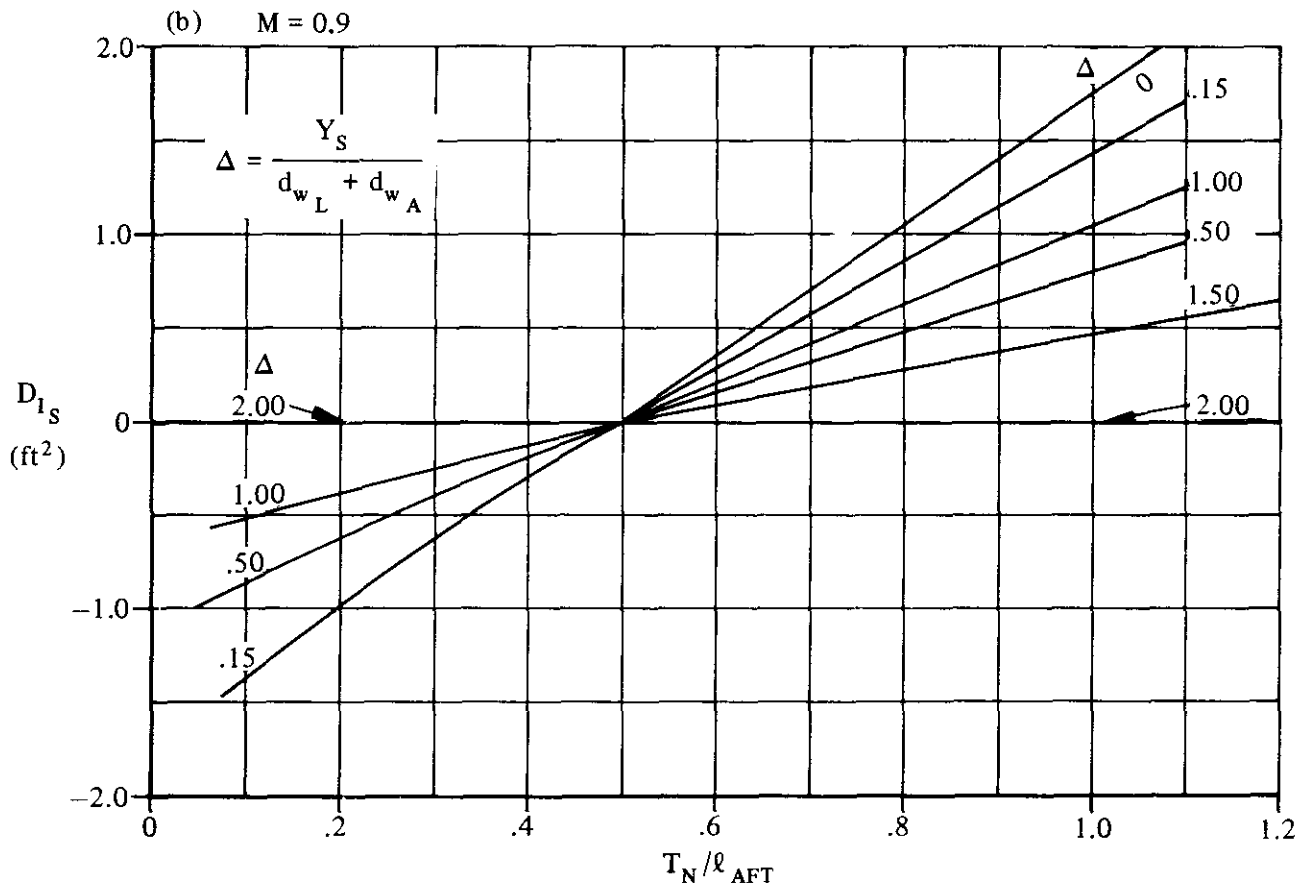


FIGURE 3.2.1.2-4 (CONTD)

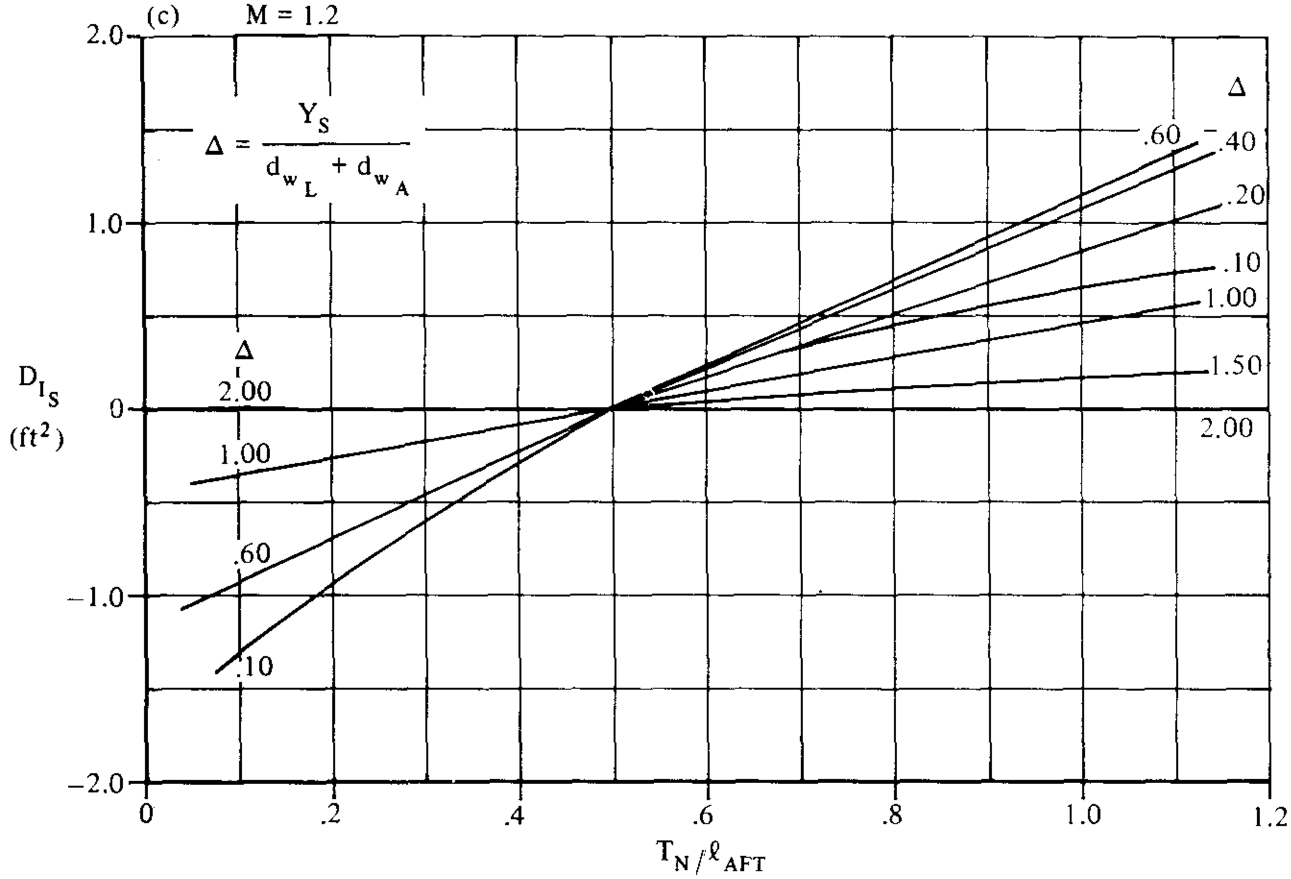


FIGURE 3.1.2-4 (CONTD)

3.2.1.3 DRAG DUE TO FUSELAGE INTERFERENCE

A method is presented in this section for estimating the zero-lift equivalent-parasite-drag area due to the mutual interference effect of a store installation and the adjacent fuselage. This effect is present for wing-mounted stores on high-wing aircraft which are mounted sufficiently close to the fuselage. The interference effect on low-wing aircraft is negligible.

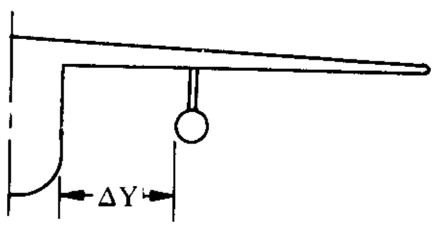
The Datcom Method is taken from Reference 1 and is empirical in nature. The method is applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The limitations on configuration and Mach-number range are summarized in Table 3.2-A, with the following exception: The method is valid to a maximum Mach number of 0.95. The design curves should not be extrapolated to higher Mach numbers due to the uncertain nature of the interference effects. Caution should be used in extrapolating the curves below M = 0.6. The method has not been verified for configurations in which flaps, slats, or other flow-disrupting devices are deployed.

A. SUBSONIC

DATCOM METHOD

The zero-lift equivalent-parasite-drag area (ft^2) due to the mutual interference of store installation and adjacent fuselage is given by D_{I_f} where D_{I_f} is obtained from Figure 3.2.1.3-3 as a function of Mach number and the minimum clearance between the store installation and the fuselage, ΔY (in.). (See Sketch (a).)

Note that $D_{I_f} = 0$ for low-wing aircraft.



SKETCH (a)

Sample Problem

Given: A high-wing aircraft with a pylon-mounted single store as shown in Sketch (a).

$M = 0.75 \qquad \Delta Y = 12$ in.

Solution:

$D_{I_f} = 0.290\ ft^2$ (Figure 3.2.1.3-3)

B. TRANSONIC

The method presented in Paragraph A of this section can be applied in the transonic speed range up to a Mach number of 0.95. Extrapolation of the data beyond this Mach number is not recommended due to the uncertain nature of the interference effects.

C. SUPERSONIC

No method is presented to estimate the fuselage-interference effect on drag in the supersonic speed range.

REFERENCE

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

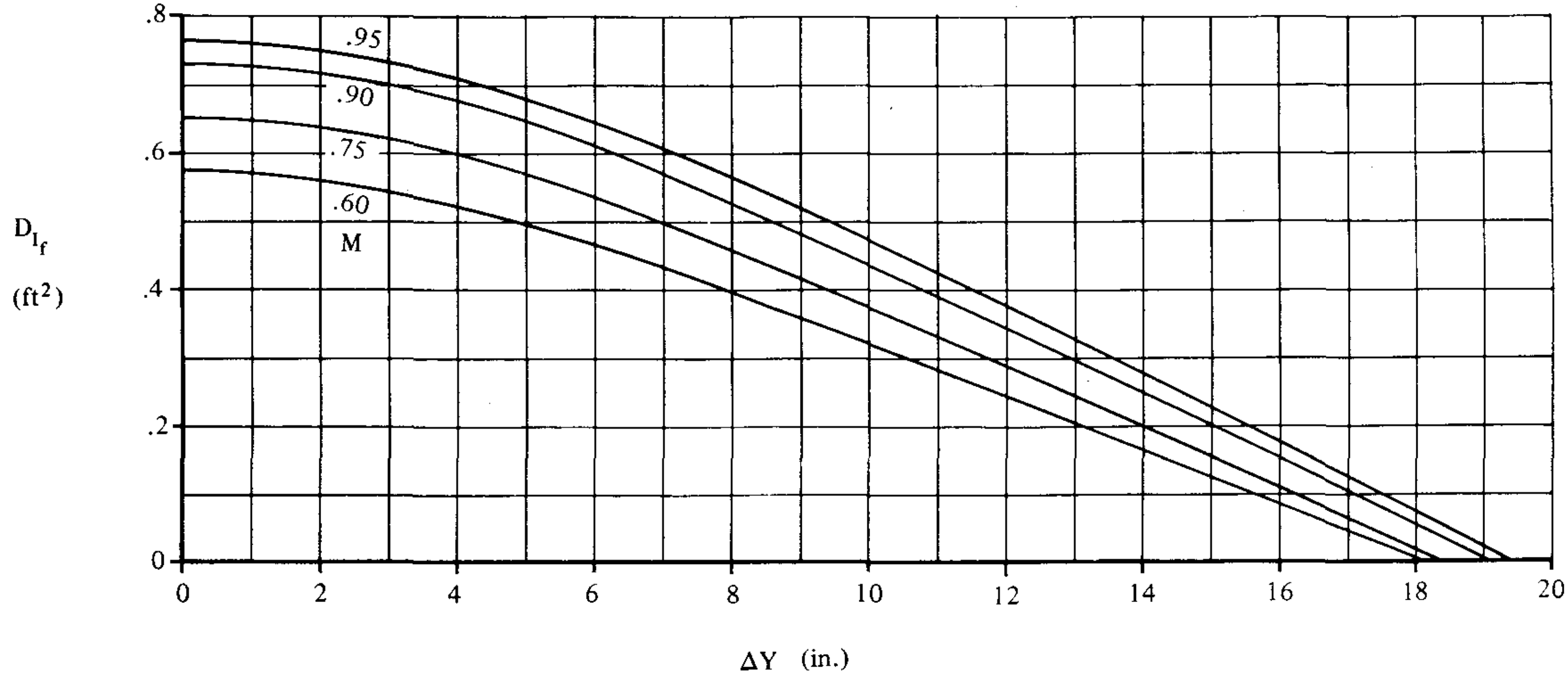


FIGURE 3.2.1.3-3 EQUIVALENT-PARASITE-DRAG AREA DUE TO MUTUAL INTERFERENCE OF STORE INSTALLATION AND ADJACENT FUSELAGE

3.2.2 DRAG DUE TO LIFT

A method is presented in this section for estimating the lift-induced equivalent-parasite-drag area due to an external-store installation. The method is applied separately to each installation (armament station). For all fuselage-mounted store installations, the equivalent-parasite-drag area due to lift is considered to be negligible.

The Datcom Method is taken from Reference 1 and is empirical in nature. The method is applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The limitations on configuration and Mach-number range are summarized in Table 3.2-A. Additional limitations and assumptions pertaining to the method are listed below:

1. The empirical design curves used in the method do not provide data below $M = 0.6$, although the method has been verified for some cases below this speed. Caution should be used when extrapolating the curves below the given Mach-number range.

2. The method is not applicable to wing-tip and wing-tangent-mounted stores.

3. The method has not been verified for configurations in which flaps, slats or other flow-disrupting devices are deployed.

4. The angle-of-attack is from zero to cruise angle of attack.

5. The data base used in deriving the method relied heavily on swept-wing tactical-combat-aircraft wind-tunnel data.

6. The method is applicable for sideslip angles less than 4°.

A. SUBSONIC

DATCOM METHOD

The store-installation drag due to lift is a function of aircraft lift coefficient, wing aspect ratio, and an empirical factor. This drag contribution is negative for all configurations for which the method is applicable. For wing-pylon-mounted-store installations, the equivalent-parasite-drag area (ft^2) due to lift is given by

$$D_i = 46.875\, C_L A_W R_i \qquad 3.2.2\text{-a}$$

where

C_L is the aircraft lift coefficient with store effects based on S_W. This term should be obtained from test data or can be estimated using Sections 3.1.3 and 4.5.1.1.

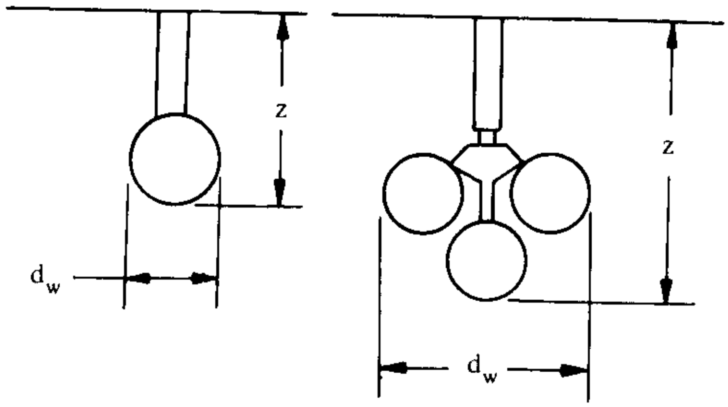
A_W is the wing aspect ratio, based on the total trapezoidal planform.

R_i is the normalized, incremental drag due to lift obtained from Figure 3.2.2-3 as a function of z, d_w, and Mach number where

z is the maximum depth of the store installation (in.). (See Sketch (a).)

d_w is the maximum width of the store installation (in.). (See Sketch (a).)

It is necessary to use interpolation for Mach numbers not presented in the figures.



SKETCH (a)

Sample Problem

Given: A swept-wing subsonic fighter aircraft (Reference 2) symmetrically loaded at the inboard-wing stations with pylon-mounted TER's, each containing two 500-lb bombs. This is the same configuration analyzed in the Sample Problem of Paragraph A of Section 3.2.1.1.

Additional Data:

$M = 0.6 \quad \alpha = 8^\circ \quad C_L = 0.185 \quad A_W = 2.91 \quad z = 38.1 \text{ in.} \quad d_w = 25.6 \text{ in.}$

Compute:

$$\frac{z\,d_w}{144} = \frac{(25.6)(38.1)}{144} = 6.77 \text{ ft}^2$$

$$R_i = -0.0025 \qquad \text{(Figure 3.2.2-3)}$$

Solution:

$$D_i = 46.875\, C_L A_W R_i \qquad \text{(Equation 3.2.2-a)}$$

$$= (46.875)(0.185)(2.91)(-0.0025)$$

$$= -0.063 \text{ ft}^2$$

This result is used in the Sample Problem of Paragraph A of Section 3.2.3 as part of the total-drag-increment computation.

B. TRANSONIC

The method presented in Paragraph A of this section is applicable in the transonic speed range.

C. SUPERSONIC

The method presented in Paragraph A of this section is applicable in the supersonic speed range up to a Mach number of 1.6. The user should use caution in extrapolating the method beyond this speed.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer. McDonnell Douglas Corporation Report DAC-67425, 1968. (U)

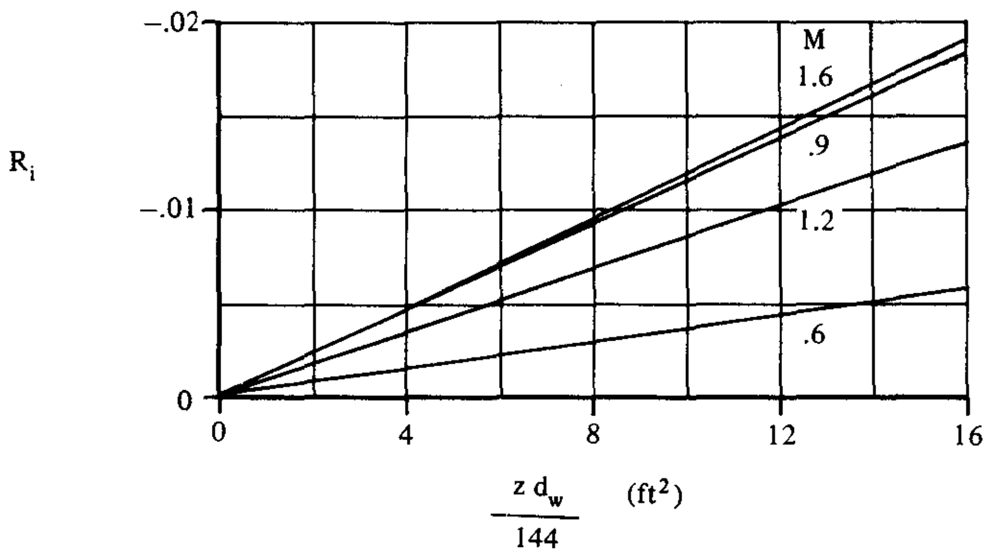


FIGURE 3.2.2-3 NORMALIZED INCREMENTAL DRAG DUE TO LIFT

3.2.3 TOTAL DRAG INCREMENT DUE TO EXTERNAL STORES

A method is presented in this section for estimating the total incremental change in aircraft drag coefficient due to external-store installations. The method predicts the increments for symmetric, asymmetric, and multiple-installation loading configurations. The total drag increment is the sum of the incremental drag at zero lift and the incremental drag due to lift. These components are computed in terms of equivalent-parasite-drag area for each installation by the methods of Sections 3.2.1 and 3.2.2, and combined to obtain the total–drag–coefficient increment by the method of this section.

The Datcom Method is taken from Reference 1 and is empirical in nature. The method is applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The limitations on configuration and Mach-number range are summarized in Table 3.2-A. Additional limitations and assumptions pertaining to the method are listed below:

1. The method has been verified for the Mach-number range given in Table 3.2-A. The user should use caution in extrapolating the empirical curves beyond the given Mach-number range.

2. The method is not applicable to wing-tip and wing-tangent-mounted stores.

3. The method has not been verified for configurations in which flaps, slats, or other flow-disrupting devices are deployed.

4. The angle-of-attack range is from zero to cruise angle of attack.

5. The data base used in deriving the method relied heavily on swept-wing tactical-combat-aircraft wind-tunnel data.

6. The method is applicable for sideslip angles less than 4°.

The procedure for computing the total–drag–coefficient increment is a summation process in which equivalent-parasite-drag areas for each store installation (armament station) are added together and divided by the wing reference area. Zero-lift-drag contributions are computed by the methods of Section 3.2.1. These include contributions of the basic installation (computed in Section 3.2.1.1), adjacent-store interference (computed in Section 3.2.1.2), and fuselage interference (computed in Section 3.2.1.3). Drag-due-to-lift contributions are computed in Section 3.2.2.

A. SUBSONIC

DATCOM METHOD

The total-aircraft drag-coefficient increment due to external-store installations and based on wing reference area, S_W, is given by

$$\Delta C_D = \frac{1}{S_W}\left\{\sum_{j=1}^{N_I} (D_B)_j + \sum_{k=0}^{N_P} \left(D_{I_S}\right)_k + \sum_{\ell=0}^{N_F} \left(D_{I_f}\right)_\ell + \sum_{m=1}^{N_I} (D_i)_m\right\} \qquad \text{3.2.3-a}$$

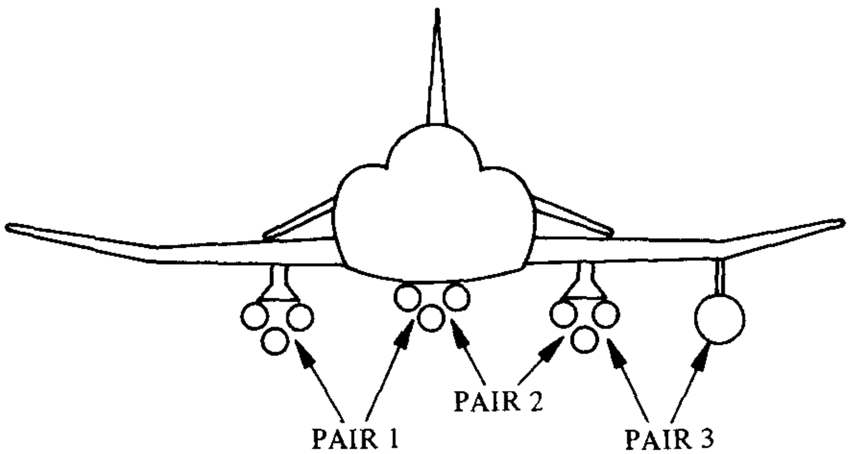
where

S_W is the aircraft wing reference area (ft^2).

N_I is the total number of store installations on the aircraft.

$(D_B)_j$ is the zero-lift equivalent-parasite-drag area (ft^2) at installation j, computed in Section 3.2.1.1.

N_P is the total number of pairs of adjacent-store installations carried. (See Sketch (a).)



SKETCH (a)

$\left(D_{I_S}\right)_k$ is the zero-lift equivalent-parasite-drag area (ft^2) due to the mutual interference of adjacent-store installations for pair k, computed in Section 3.2.1.2.

N_F is the number of store installations adjacent to the fuselage.

$\left(D_{I_f}\right)_\ell$ is the zero-lift equivalent-parasite-drag area (ft^2) due to the mutual interference of store installation ℓ and adjacent fuselage, computed in Section 3.2.1.3.

$(D_i)_m$ is the drag-due-to-lift equivalent-parasite-drag area (ft^2) at installation m, computed in Section 3.2.2.

Reference 1 states that prediction errors for store incremental-drag are nominally 10 to 15 percent, resulting in an overall accuracy within 5 percent of the total-aircraft-drag coefficient. A comparison of test data with results calculated by this method is provided in Table 3.2.3-A. Additional comparisons of test and calculated results are found in Reference 1.

Sample Problem

Given: A swept-wing subsonic fighter aircraft (Reference 2) symmetrically loaded at the inboard-wing stations with pylon-mounted TER's, each containing two 500-lb bombs. This is the same low-wing configuration presented in the Sample Problems of Paragraph A of Section 3.2.1.1 and Paragraph A of Section 3.2.2.

Additional Characteristics:

$M = 0.6$ $\quad\quad$ $S_W = 260 \text{ ft}^2$

(Additional geometric data are provided in the Sample Problems of Sections 3.2.1.1 and 3.2.2.)

$D_B = 1.498 \text{ ft}^2$ (1 side) (Sample Problem, Paragraph A, Section 3.2.1.1)

$D_i = -0.063 \text{ ft}^2$ (1 side) (Sample Problem, Paragraph A, Section 3.2.2)

$D_{I_f} = 0$ (low-wing configuration)

Compute:

$N_I = 2$ (two store installations)

$N_P = 0$ (No pairs of adjacent store installations)

$N_F = 2$

Solution:

$$\Delta C_D = \frac{1}{S_W}\left\{\sum_{j=1}^{N_I}(D_B)_j + \sum_{k=1}^{N_P}\left(D_{I_S}\right)_k + \sum_{\ell=1}^{N_F}\left(D_{I_f}\right)_\ell + \sum_{m=1}^{N_I}(D_i)_m\right\} \quad \text{(Equation 3.2.3-a)}$$

Expanding and noting that $N_P = 0$ and $\left(D_{I_f}\right)_\ell = 0$,

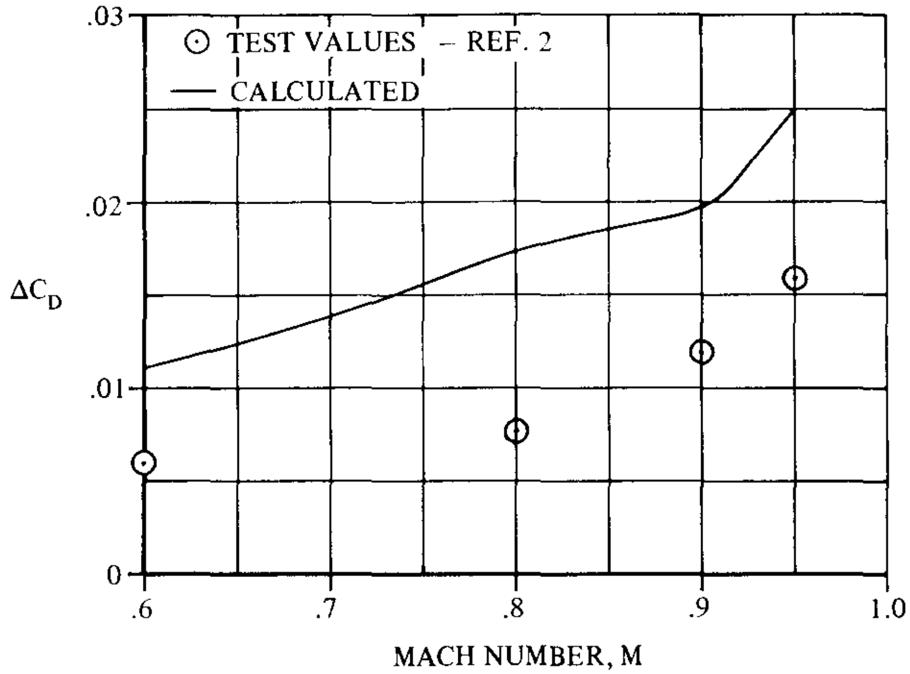
$$\Delta C_D = \frac{1}{S_W}\left[(D_B)_1 + (D_B)_2 + (D_i)_1 + (D_i)_2\right]$$

$$= \frac{1}{S_W}\left[2D_B + 2D_i\right] \quad \text{(symmetrical installations)}$$

$$= \frac{1}{260}\left[(2)(1.498) + (2)(-0.063)\right]$$

$$= 0.0110$$

Values of ΔC_D at other Mach numbers are shown in comparison to test data from Reference 2 in Sketch (b).



SKETCH (b)

B. TRANSONIC

The method presented in Paragraph A of this section is also valid in the transonic speed range. The user is cautioned that due to the difficulties of predicting drag in the transonic region (especially interference effects), the method is generally less accurate than in the subsonic and supersonic speed ranges.

C. SUPERSONIC

The method presented in Paragraph A of this section is also valid in the supersonic speed range up to the Mach-number limits indicated in Table 3.2-A. Caution should be used when extrapolating data from the figures beyond the given Mach-number range since the method has not been substantiated beyond these limits.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer. McDonnell Douglas Corporation Rept. DAC-67425, 1968. (U)

3. Bonine, W. J., et al.: Model F/RF-4B-C Aerodynamic Derivatives. McDonnell Douglas Corporation Rept. 9842, 1964 (Rev. 1971). (U)

TABLE 3.2.3-A

SUBSONIC EXTERNAL-STORE DRAG
DATA SUMMARY AND SUBSTANTIATION

Ref	Loading Description	α	M	ΔC_D calc	ΔC_D test	ΔC_D calc-test
2	Wing Station Mounting Left Inboard Pylon: Empty	Cruise	0.6 0.8 0.9 0.95	0.00061 0.00066 0.00087 0.00113	0.00060 0.00071 0.00090 0.00105	0.00001 −0.00005 −0.00003 0.00008
	Fuselage Station Mounting Centerline Pylon: Empty	Cruise	0.6 0.8 0.9 0.95	0.00044 0.00052 0.00067 0.00084	0.00061 0.00076 0.00098 0.00117	−0.00017 −0.00024 −0.00031 −0.00033
	Wing Station Mounting Left Inboard Pylon-Mounted Single: 500-lb bomb	Cruise	0.6 0.8 0.9	0.00141 0.00139 0.00169	0.00090 0.00111 0.00195	0.00051 0.00028 −0.00026
	Wing Station Mounting Left Inboard Pylon-Mounted TER: 2 500-lb bombs Right Inboard Pylon-Mounted TER: 2 500-lb bombs	Cruise	0.6 0.8 0.9 0.95	0.0110 0.0172 0.0195 0.0250	0.0058 0.0076 0.0117 0.0166	0.0052 0.0096 0.0078 0.0084
	Wing Station Mounting Left Inboard Pylon-Mounted MER: Empty	Cruise	0.6 0.8 0.9 0.95	0.00308 0.00446 0.00540 0.00582	0.00270 0.00344 0.00490 0.00605	0.00038 0.00102 0.00050 −0.00023
3	Fuselage Station Mounting Tangent-Mounted Tandem: 4 missiles	Cruise	0.6	0.00097	0.00100	−0.00003

$$\text{Average Error } \sum \frac{\left|\Delta C_{D_{\text{Calc-Test}}}\right|}{n} = 0.00180$$

3.3 EFFECT OF EXTERNAL STORES ON AIRCRAFT NEUTRAL POINT

Methods are presented in this section for estimating the incremental shift in aircraft neutral point due to external-store installations. By computing a neutral-point shift due to external stores, the methods are actually indicating a stability change in terms of a change in slope of the $C_M - C_L$ curve. For most configurations the effect of store loadings is to destabilize the basic aircraft, although some loadings can result in a stabilizing tendency. The methods are taken from Reference 1 and are empirical in nature.

Section 3.3 is subdivided as follows:

Section 3.3.1 Neutral-Point Shift Due to Lift Transfer from Clean Aircraft.
Section 3.3.2 Neutral-Point Shift Due to Interference Effects on Wing Flow Field.
Section 3.3.3 Neutral-Point Shift Due to Change in Tail Effectiveness.
Section 3.3.4 Total Neutral-Point Shift Due to External Stores.

The total neutral-point shift is the sum of the shifts computed by the methods of Sections 3.3.1, 3.3.2, and 3.3.3.

The Datcom Methods are applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The methods are limited to the store-loading configurations and Mach-number range presented in Table 3.3-A. The methods are applicable to mixed loading configurations obtained by combining two or more loadings specified in Table 3.3-A. The methods are subject to additional limitations specifically noted in each of the sections that follow.

TABLE 3.3-A

LOADING AND FLIGHT CONDITION LIMITATIONS

Mounting Location	Carriage Mode	Carriage Rack	Mach Number Range	C_L Range
Wing	Single	Pylon	0.6 → 2.0	0 → 0.2
	Multiple	MER – Fully Loaded	0.6 → 1.6	
		MER – Partially Loaded		
		TER – Fully Loaded		
		TER – Partially Loaded		
Fuselage (Centerline)	Single	Pylon		
		Tangent Mounted		
	Multiple	Pylon + MER		
		Tangent MER		

REFERENCE

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

3.3.1 NEUTRAL-POINT SHIFT DUE TO LIFT TRANSFER FROM STORE INSTALLATION TO CLEAN AIRCRAFT

A method is presented in this section for estimating the neutral-point shift due to the transfer of the lifting characteristics from the external-store installations to the clean aircraft. The method predicts a neutral-point shift due to all installations (armament stations) on the aircraft. Wing-flow-field interference and horizontal-tail effects are not included in this section (see Sections 3.3.2 and 3.3.3).

The Datcom Method is taken from Reference 1 and is basically theoretical in concept with empirically-determined factors and coefficients. The method is applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The limitations on configuration and Mach-number range are summarized in Table 3.3-A. Additional limitations and assumptions pertaining to the method are listed below:

1. The method is not applicable to wing-tip or wing-tangent-mounted stores.

2. The method has been verified for the Mach-number range given in Table 3.3-A. Caution should be used in extrapolating the empirical curves beyond the given Mach-number range.

3. The method has not been verified for configurations in which flaps, slats or other flow-disrupting devices are deployed.

4. The method gives the best results for an angle-of-attack range from 0 to 8°, although the method can be used for higher angles of attack.

5. The data base used in deriving the method relied heavily on swept-wing tactical-combat-aircraft wind-tunnel data.

6. The method is applicable for sideslip angles less than 4°.

7. Fuselage-mounted installations must be located on the fuselage centerline.

8. The method is not applicable to empty multiple racks.

9. The effect of empty pylons on neutral point is considered to be negligible.

The effect due to a pair of symmetrical installations can be computed by doubling the effect of one side.

A. SUBSONIC

DATCOM METHOD

The neutral-point shift in inches, positive for aft shift, due to the transfer of lift from the store installations to the clean aircraft is given by

$$\Delta x_{n.p._I} = \frac{\sum_{i=1}^{N_I} \sum_{j=1}^{n_{s_i}} K_{S_{ij}} C_{L_{\alpha_{S_{ij}}}} \left(x_{S_{ij}} - x_{a.c.}\right)}{C_{L_{\alpha_{WB}}} + \sum_{i=1}^{N_I} \sum_{j=1}^{n_{s_i}} K_{S_{ij}} C_{L_{\alpha_{S_{ij}}}}} \qquad 3.3.1\text{-a}$$

where

N_I is the total number of store installations.

i is the store-installation number.

n_{s_i} is the number of store stations on installation i (including empty stations).

j is the store number on installation i.

$C_{L_{\alpha_{S_{ij}}}}$ is the free-stream lift-curve slope of store j on installation i given by

$$C_{L_{\alpha_{S_{ij}}}} = \frac{375}{S_W} \left[\left(C_{L_\alpha}\right)_{SB} \left(K_{NB}\right) + \left(C_{L_\alpha}\right)_{SF}\right] \text{ (per deg)} \qquad 3.3.1\text{-b}$$

where

S_W is the aircraft wing reference area (ft^2).

$\left(C_{L_\alpha}\right)_{SB}$ is the store-body lift-curve slope (per deg) obtained from Figure 3.3.1-16 as a function of store-body planform area, S_p ($in.^2$).

K_{NB} is a nose-shape parameter given by

$$K_{NB} = 1.0 \text{ for } \theta_n \leqslant 22^\circ \qquad 3.3.1\text{-c}$$

$$K_{NB} = 1.0 + 0.65 \frac{(\theta_n - 22)}{68} \text{ for } 22^\circ < \theta_n \leqslant 90^\circ \qquad 3.3.1\text{-d}$$

where

θ_n is the store-nose half-cone angle (deg).

$\left(C_{L_\alpha}\right)_{SF}$ is the store-fin lift-curve slope (per deg) given by

$$\left(C_{L_\alpha}\right)_{SF} = (0.191)(10^{-6})(B_e)^2 \qquad 3.3.1\text{-e}$$

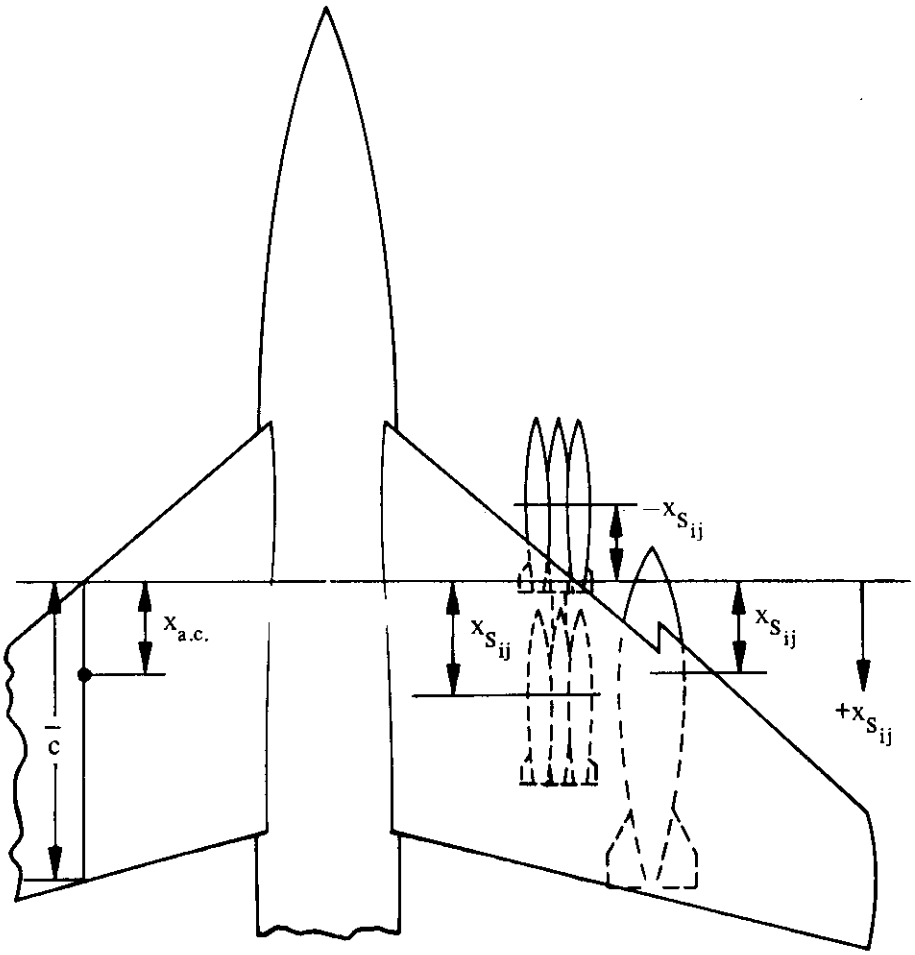
where

$$B_e = 0 \text{ for } b_F \leqslant d_S \qquad 3.3.1\text{-f}$$

$$B_e = b_F - d_S \text{ for } b_F > d_S \qquad 3.3.1\text{-g}$$

where b_F and d_S are the store-fin span and maximum store diameter (in.), respectively.

$x_{S_{ij}}$ is the distance (in.) from the leading edge of the mean aerodynamic chord $\bar{c}$, to the point midway between the mounting lugs of the installed store for store j on installation i, positive in the aft direction. (See Sketch (a).)



SKETCH (a)

$x_{a.c.}$ is the wing-body aerodynamic-center location of the clean aircraft measured from the leading edge of the wing mean aerodynamic chord (in.). (See Sketch (a).) This value should be obtained from test data or estimated by using Section 4.3.2.2.

$C_{L_{\alpha_{WB}}}$ is the wing-body clean-aircraft lift-curve slope (per deg) obtained from test data or estimated by using Section 4.3.1.2.

$K_{S_{ij}}$ is an empirical factor related to installation type, mounting position, and Mach number and is specified as follows:

1. Wing-Pylon-Mounted Single Store:

In this case $n_{s_i} = 1$ and hence $j = 1$.

$$K_{S_{ij}} = F_1\left(\bar{x}_{SN_{ij}}, F_R\right) + F_2\left(\bar{x}_{SN_{ij}}, z_{ij}, F_R\right) \quad i = 1, \ldots N_I \qquad 3.3.1\text{-h}$$

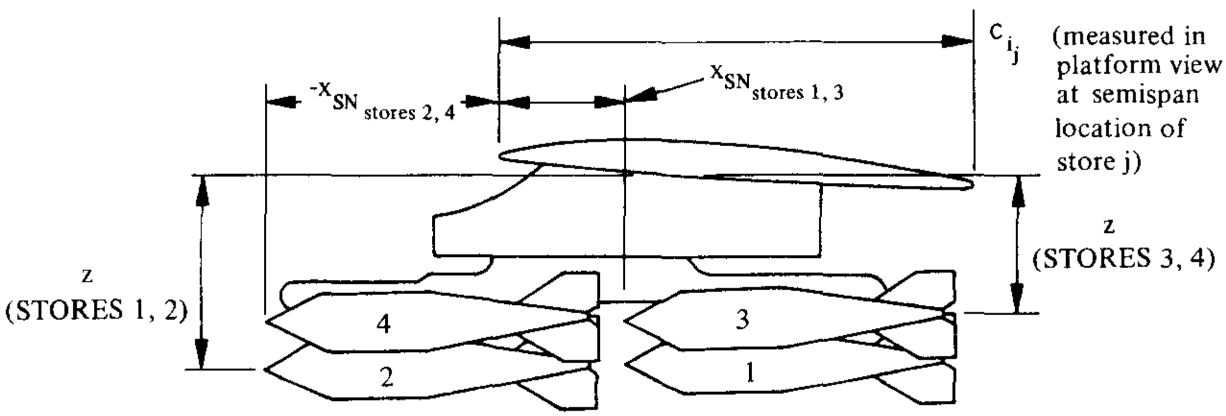
where $F_1\left(\bar{x}_{SN_{ij}} F_R\right)$ is a parameter based on store longitudinal placement and fin-area ratio obtained from Figure 3.3.1-17.

where

$$\bar{x}_{SN_{ij}} = \frac{x_{SN_{ij}}}{c_{ij}} \quad \text{for } j = 1 \qquad 3.3.1\text{-i}$$

where

$x_{SN_{ij}}$ is the distance from the local wing leading edge to nose of store j on installation i, positive in the aft direction (in.). (See Sketch (b).)



SKETCH (b)

c_{ij} is the local wing chord at the semispan location of store j on store installation i, (in.). (See Sketch (b).)

F_R is given by

$$F_R = \frac{S_F}{S_p} \qquad 3.3.1\text{-j}$$

where

S_F is the store-fin area projected onto a horizontal plane (in.^{2}).

S_p is the store-body planform area (in.^{2}).

$F_2\left(\bar{x}_{SN_{ij}}, \bar{z}_{ij}, F_R\right)$ is given by

$$F_2\left(\bar{x}_{SN_{ij}}, \bar{z}_{ij}, F_R\right) = F_{21}\left(\bar{x}_{SN_{ij}}\right) F_{22}(\bar{z}_{ij}) F_{23}(F_R) \qquad 3.3.1\text{-k}$$

where

$F_{21}\left(\bar{x}_{SN_{ij}}\right)$ is a store longitudinal-placement factor obtained from Figure 3.3.1-18a where $\bar{x}_{SN_{ij}}$ is given by Equation 3.3.1-i.

$F_{22}(\bar{z}_{ij})$ is a store vertical-placement factor obtained from Figure 3.3.1-18b where $\bar{z}_{ij}$ is obtained from

$$\bar{z}_{ij} = \frac{z_{ij}}{c_{ij}} \text{ for } j = 1 \qquad 3.3.1\text{-}\ell$$

where

z_{ij} is the vertical distance from the average wing lower surface location to the centerline of store j on installation i, positive in downward direction (in.). (See Sketch (b).)

c_{ij} is the local wing chord at the semispan location of store j on store installation i (in.). (See Sketch (b).)

$F_{23}(F_R)$ is a store-fin area-ratio factor obtained from Figure 3.3.1-19a where F_R is given by Equation 3.3.1-j.

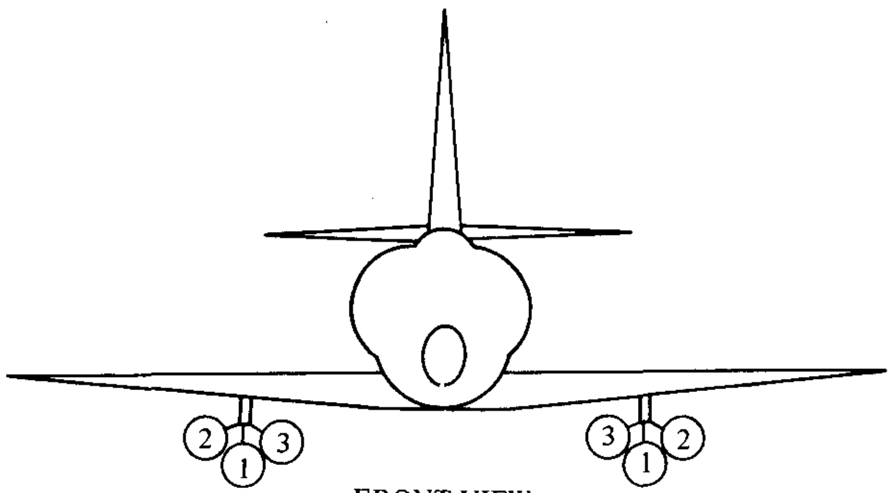
2. Wing-Pylon-Mounted TER (For TER installations it is essential that the store stations be identified in the same manner as indicated in Sketch (c).)

$$K_{S_{ij}} = F_1\left(\bar{x}_{SN_{ij}}\right) + F_2(M, j) \quad j = 1, 2, 3 \qquad 3.3.1\text{-m}$$

where

$F_1\left(\bar{x}_{SN_{ij}}\right)$ is a store longitudinal-placement parameter for TER carriage obtained from Figure 3.3.1-19b where $\bar{x}_{SN_{ij}}$ is given by Equation 3.3.1-i.

$F_2(M, j)$ is the TER Mach and store-station effect parameter obtained from Figures 3.3.1-20a through -20c as a function of Mach number and TER store-station number, j, where j refers to the TER station number defined in Sketch (c).



FRONT VIEW

SKETCH (c)

3. Wing-Pylon-Mounted MER (For MER installations it is essential that the store stations be identified in the same manner as indicated in Sketch (d).)

$$K_{S_{ij}} = F_1\left(\bar{x}_{SN_{ij}}\right) + F_2\left(\bar{x}_{SN_{ij}}, \bar{z}_{ij}, M\right) + F_3(M, j) \qquad 3.3.1\text{-n}$$

where

$F_1\left(\bar{x}_{SN_{ij}}\right)$ is a store longitudinal-placement parameter for MER carriage obtained from Figure 3.3.1-21 where $\bar{x}_{SN_{ij}}$ is given by Equation 3.3.1-i.

$F_2\left(\bar{x}_{SN_{ij}}, \bar{z}_{ij}, M\right)$ is given by

$$F_2\left(\bar{x}_{SN_{ij}}, \bar{z}_{ij}, M\right) = F_{21}\left(\bar{x}_{SN_{ij}}\right) F_{22}(\bar{z}_{ij}) F_{23}(M) \qquad 3.3.1\text{-o}$$

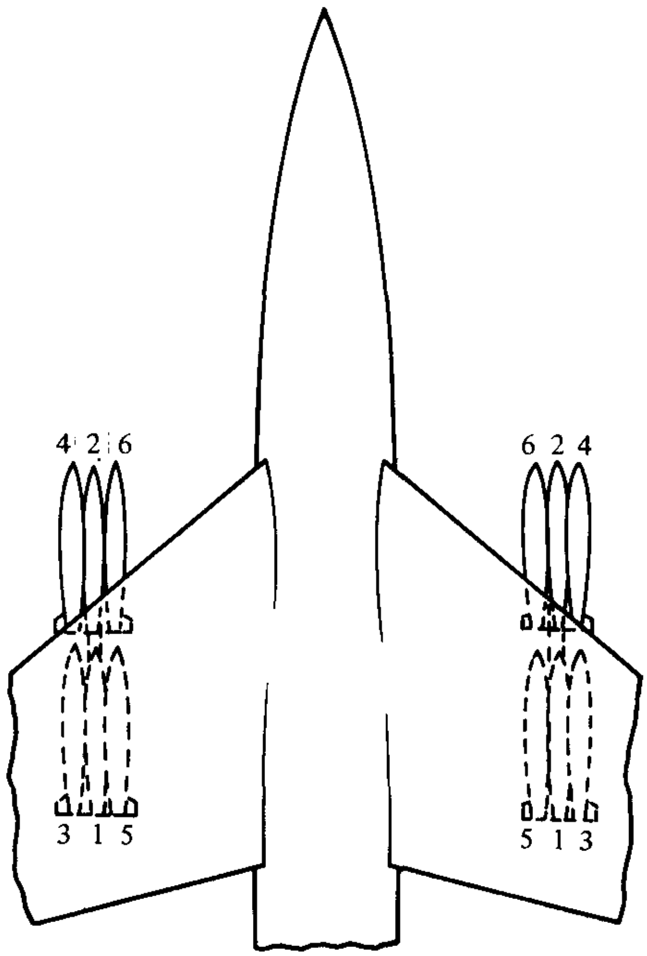
where $\bar{z}_{ij}$ is defined by Equation 3.3.1-ℓ, and

$F_{21}\left(\bar{x}_{SN_{ij}}\right)$ is a MER store longitudinal-placement factor obtained from Figures 3.3.1-22a and -22b.

$F_{22}(\bar{z}_{ij})$ is a MER store vertical-placement factor obtained from Figures 3.3.1-23a and -23b.

$F_{23}(M)$ is a MER Mach-effect factor obtained from Figures 3.3.1-24a and -24b.

$F_3(M, j)$ is the MER Mach and store-station effect parameter obtained from Figures 3.3.1-25a through -25f as a function of Mach number and MER store-station number, j, where j refers to the MER store-station number defined in Sketch (d).



TOP VIEW

SKETCH (d)

4. Fuselage-Centerline-Mounted Single Carriage

In this case $n_{s_j} = 1$ and hence $j = 1$

$$K_{S_{ij}} = 0.10 \qquad 3.3.1\text{-p}$$

5. Fuselage-Centerline-Tangent-Mounted MER (For fuselage MER installations, use the right wing numbering scheme of Sketch (d) for numbering the store station locations.)

$$K_{S_{ij}} = I_{S_j} [F_1(M) + F_2(M, j)] \quad (j = 1, 2, 3, 4, 5, 6) \qquad 3.3.1\text{-q}$$

where j coincides with the MER station number defined by Sketch (d).

For j = 1, 2

$$I_{S_j} = 1.0 \qquad 3.3.1\text{-r}$$

For j = 3, 4, 5, 6

I_{S_j} is a neutral-point correlation factor for stores on a MER installation obtained from Figure 3.3.1-27a as a function of d_{wing}/c_r where d_{wing} is the distance (in.) from the fuselage lower surface at the store midpoint to the average wing lower surface at the wing root and c_r is the wing root chord (in.).

$F_1(M)$ is a MER Mach-effect factor for fuselage-tangent-mounted installations obtained from Figure 3.3.1-27b as a function of Mach number.

$F_2(M, j)$ is a MER Mach and store-station effect parameter for fuselage-tangent-mounted installations obtained from Figures 3.3.1-28a through -28d as a function of Mach number and MER station, j.

6. Fuselage-Centerline-Pylon-Mounted MER (For fuselage MER installations, use the right wing numbering scheme of Sketch (d) for numbering the store station locations.)

For j = 1, 3, 5 where j are the MER stations defined in Sketch (d),

$$K_{S_{ij}} = I_{S_j} F_1(M) \qquad 3.3.1\text{-s}$$

where

I_{S_j} is defined for Configuration 5.

$F_1(M)$ is a MER Mach-effect factor for fuselage-pylon-mounted installations obtained from Figure 3.3.1-30a as a function of Mach number and MER station, j.

For j = 2,

$$K_{S_{ij}} = F_1(M) \qquad 3.3.1\text{-t}$$

where

$F_1(M)$ is obtained from Figure 3.3.1-45b

For j = 4, 6

$$K_{S_{ij}} = I_{S_j}\,[F_1(M) + F_2(M, j)] \qquad 3.3.1\text{-u}$$

where

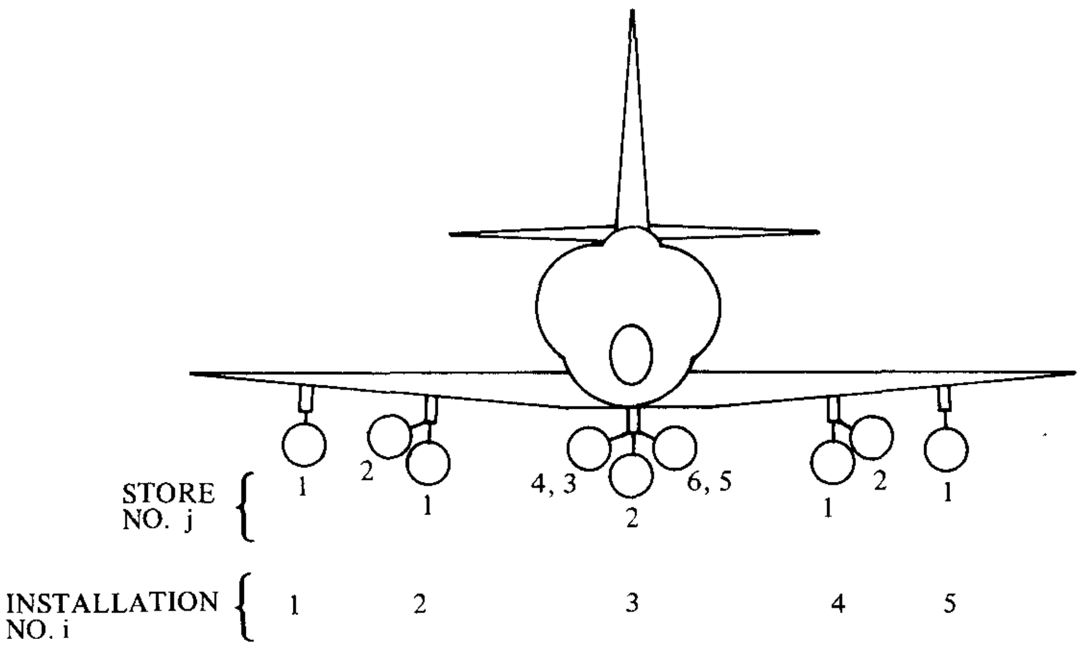
I_{S_j} is defined for Configuration 5.

$F_1(M)$ is a MER Mach-effect factor for fuselage-pylon-mounted installations obtained from Figure 3.3.1-30b as a function of Mach number and MER station, j.

$F_2(M, j)$ is a MER Mach and store-station effect parameter for fuselage-pylon-mounted installations obtained from Figure 3.3.1-31 as a function of configuration and Mach number.

Sample Problem

Given: A swept-wing subsonic fighter aircraft from Reference 2, symmetrically loaded as follows:



FRONT VIEW

Spanwise Station	Rack Type	Mounting	Store Type	No. of Stores
Centerline	MER	Pylon	500-lb Bomb	5
Inboard Wing	TER	Pylon	500-lb Bomb	2
Outboard Wing	Single	Pylon	500-lb Bomb	1

Aircraft Data:

$S_W = 260 \text{ ft}^2$ $\qquad \bar{c} = 129.6$ in. $\qquad c_r = 186$ in.

$d_{wing} = 0$ $\qquad x_{a.c.} = 33.05$ in. $\qquad C_{L_{\alpha_{WB}}} = 0.060$ per deg

i	j	Wing Semispan Station, y_{ij} (in.)	c_{ij} (in.)
1,5	1	113.75	87.8
2,4	2	87.00	111.0
2,4	1	78.80	119.0

Isolated-Store Data:

$d_S = 12.0$ in. $\qquad S_p = 700 \text{ in.}^2$ $\qquad S_F = 94 \text{ in.}^2$

$b_F = 14.7$ in. $\qquad \theta_n = 17^{\circ}$

Store Installation Data:

Installation Number, i	Store No., j	$x_{SN_{ij}}$ (in.)	$x_{S_{ij}}$ (in.)	z_{ij} (in.)	y_{ij} (in.)
2,4	1	−21.7	31.7	–	78.8
2,4	2	−30.0	31.7	–	87.0
1,5	1	−23.2	61.2	17.6	113.75
3	3,5	–	71.7	–	0
3	2,4,6	–	−22.4	–	0

Additional Data:

$M = 0.6$ $\qquad \alpha = 8^{\circ}$

Compute:

To identify the terms that need to be computed, expand Equation 3.3.1-a for the N_I store installations and n_{s_i} stores on each installation. Since the aircraft is symmetrically loaded with respect to the fuselage centerline, installations 1 and 5 are identical, as are 2 and 4. Therefore, it is only necessary to compute the terms (in Equation 3.3.1-a) for installations 1 and 2, and then double their values. The results are then added to the terms for installation 3. The indices for the summation process are summarized in the table below:

i	n_{s_i}	Actual Store Stations Loaded on Installation i
1	1	j = 1
2	3	j = 1, 2
3	6	j = 2, 3, 4, 5, 6

Note that for i = 2, station 3 is not loaded and for i = 3, station 1 is not loaded. Therefore, terms for these locations are set equal to zero.

$\Delta x_{n.p._1}$ numerator (from Equation 3.3.1-a):

$$\sum_{i=1}^{N_I} \sum_{j=1}^{n_{s_i}} K_{S_{ij}} C_{L_{\alpha_{ij}}} \left(x_{S_{ij}} - x_{a.c.}\right) =$$

$$2\left[K_{S_{11}} C_{L_{\alpha_{S_{11}}}} \left(x_{S_{11}} - x_{a.c.}\right) + K_{S_{21}} C_{L_{\alpha_{S_{21}}}} \left(x_{S_{21}} - x_{a.c.}\right)\right.$$

$$\left. + K_{S_{22}} C_{L_{\alpha_{S_{22}}}} \left(x_{S_{22}} - x_{a.c.}\right)\right] + K_{S_{32}} C_{L_{\alpha_{S_{32}}}} \left(x_{S_{32}} - x_{a.c.}\right)$$

$$+ K_{S_{33}} C_{L_{\alpha_{S_{33}}}} \left(x_{S_{33}} - x_{a.c.}\right) + K_{S_{34}} C_{L_{\alpha_{S_{34}}}} \left(x_{S_{34}} - x_{a.c.}\right)$$

$$+ K_{S_{35}} C_{L_{\alpha_{S_{35}}}} \left(x_{S_{35}} - x_{a.c.}\right) + K_{S_{36}} C_{L_{\alpha_{S_{36}}}} \left(x_{S_{36}} - x_{a.c.}\right)$$

$\Delta x_{n.p._1}$ denominator (from Equation 3.3.1-a):

$$C_{L_{\alpha_{WB}}} + \sum_{i=1}^{N_I} \sum_{j=1}^{n_{s_i}} K_{S_{ij}} C_{L_{\alpha_{S_{ij}}}} =$$

$$C_{L_{\alpha_{WB}}} + 2\left[K_{S_{11}} C_{L_{\alpha_{S_{11}}}} + K_{S_{21}} C_{L_{\alpha_{S_{21}}}} + K_{S_{22}} C_{L_{\alpha_{S_{22}}}}\right] + K_{S_{32}} C_{L_{\alpha_{S_{32}}}} + K_{S_{33}} C_{L_{\alpha_{S_{33}}}}$$

$$+ K_{S_{34}} C_{L_{\alpha_{S_{34}}}} + K_{S_{35}} C_{L_{\alpha_{S_{35}}}} + K_{S_{36}} C_{L_{\alpha_{S_{36}}}}$$

For Installation 1 (Wing-Pylon-Mounted Single Store)

$$\bar{x}_{SN_{11}} = \frac{x_{SN_{11}}}{c_{11}} = \frac{-23.2}{87.8} = -0.264 \qquad \text{(Equation 3.3.1-i)}$$

$$F_R = \frac{S_F}{S_P} = \frac{94}{700} = 0.134 \qquad \text{(Equation 3.3.1-j)}$$

$$\bar{z}_{11} = \frac{z_{11}}{c_{11}} = \frac{17.6}{87.8} = 0.200 \qquad \text{(Equation 3.3.1-}\ell\text{)}$$

$$F_1\left(\bar{x}_{SN_{11}}, F_R\right) = -0.035 \qquad \text{(Figure 3.3.1-17)}$$

$$F_{21}\left(\bar{x}_{SN_{11}}\right) = 1.70 \qquad \text{(Figure 3.3.1-18a)}$$

$$F_{22}(\bar{z}_{11}) = 0 \qquad \text{(Figure 3.3.1-18b)}$$

$$F_{23}(F_R) = -0.53 \qquad \text{(Figure 3.3.1-19a)}$$

$$F_2\left(\bar{x}_{SN_{11}}, \bar{z}_{11}, F_R\right) = F_{21}\left(\bar{x}_{SN_{11}}\right) F_{22}(\bar{z}_{11}) F_{23}(F_R) \qquad \text{(Equation 3.3.1-k)}$$

$$= (1.70)(0)(-0.53) = 0$$

$$K_{S_{11}} = F_1\left(\bar{x}_{SN_{11}}, F_R\right) + F_2\left(\bar{x}_{SN_{11}}, \bar{z}_{11}, F_R\right) \qquad \text{(Equation 3.3.1-h)}$$

$$= -0.035 + 0 = -0.035$$

$$\left(C_{L_\alpha}\right)_{SB} = 0.161 \times 10^{-3} \text{ per deg} \qquad \text{(Figure 3.3.1-16)}$$

$$K_{NB} = 1.0 \qquad (\text{Equation 3.3.1-c}, \theta_n < 22^\circ)$$

$$B_e = b_F - d_S = 2.70 \qquad (\text{Equation 3.3.1-g}, b_F > d_S)$$

$$\left(C_{L_\alpha}\right)_{SF} = (0.191)(10^{-6})(B_e^{\,2}) \qquad \text{(Equation 3.3.1-e)}$$

$$= (0.191 \times 10^{-6})(2.7)^2$$

$$= 1.392 \times 10^{-6} \text{ per deg}$$

$$C_{L_{\alpha_{S_{11}}}} = \frac{375}{S_W}\left[\left(C_{L_\alpha}\right)_{SB} K_{NB} + \left(C_{L_\alpha}\right)_{SF}\right] \qquad \text{(Equation 3.3.1-b)}$$

$$= \frac{375}{260}[(0.161 \times 10^{-3})(1) + 1.392 \times 10^{-6}]$$

$$= 0.000233 \text{ per deg}$$

Noting that all stores are identical in this problem,

$$C_{L_{\alpha_{S_{ij}}}} = 0.000233 \text{ per deg for all i, j.}$$

For Installation 2 (Wing-Pylon-Mounted TER)

$$\bar{x}_{SN_{21}} = \frac{x_{SN_{21}}}{c_{21}} = \frac{-21.7}{119.0} = -0.182 \qquad \text{(Equation 3.3.1-i)}$$

$$\bar{x}_{SN_{22}} = \frac{x_{SN_{22}}}{c_{22}} = \frac{-30.0}{111.0} = -0.270$$

$$\left.\begin{aligned} F_1\left(\bar{x}_{SN_{21}}\right) &= 0.280 \text{ (centerline sta., j = 1)} \\ F_1\left(\bar{x}_{SN_{22}}\right) &= 0.710 \text{ (shoulder sta., j = 2)} \end{aligned}\right\} \qquad \text{(Figure 3.3.1-19b)}$$

$$F_2(M, j) = 0 \text{ for } j = 1 \qquad \text{(Figure 3.3.1-20a)}$$

$$F_2(M, j) = 0 \text{ for } j = 2 \qquad \text{(Figure 3.3.1-20b)}$$

$$K_{S_{ij}} = F_1\left(\bar{x}_{SN_{ij}}\right) + F_2(M, j) \qquad \text{(Equation 3.3.1-m)}$$

$$K_{S_{21}} = 0.280 + 0 = 0.280$$

$$K_{S_{22}} = 0.710 + 0 = 0.710$$

For Installation 3 (Fuselage-Centerline-Pylon-Mounted MER)

There are five stores on this installation, therefore determine $K_{S_{ij}} = K_{S_{3j}}$ where j = 2, 3, 4, 5, 6

For $j = 2$

$F_1(M) = 0.45$ (Figure 3.3.1-30b)

$K_{S_{ij}} = F_1(M)$ (Equation 3.3.1-t)

$K_{S_{32}} = 0.45$

For $j = 3, 5$

$$\frac{d_{wing}}{c_r} = \frac{0}{186} = 0$$

$I_{S_j} = 0$ for $j = 3, 5$ (Figure 3.3.1-27a)

$F_1(M) = 0.042$ (Figure 3.3.1-30a)

$K_{S_{ij}} = I_{S_j} F_1(M)$ (Equation 3.3.1-s)

$K_{S_{33}} = K_{S_{35}} = (0)(0.042) = 0$

For $j = 4, 6$

$I_{S_j} = 0$ for $j = 4, 6$ (Figure 3.3.1-27a)

$F_1(M) = 0.45$ for $j = 4, 6$ (Figure 3.3.1-30b)

$F_2(M, j) = 0$ for $j = 4, 6$ (Figure 3.3.1-31)

$K_{S_{ij}} = I_{S_j} [F_1(M) + F_2(M, j)]$ (Equation 3.3.1-u)

$K_{S_{34}} = K_{S_{36}} = (0)[0.45 + 0] = 0$

Substituting into the $\Delta x_{n.p._1}$ numerator:

$$\sum_{i=1}^{N_I} \sum_{j=1}^{n_{s_i}} K_{S_{ij}} C_{L_{\alpha_{S_{ij}}}} \left(x_{S_{ij}} - x_{a.c.}\right) = 2\Big[(-0.035)(0.000233)(61.2 - 33.05) + (0.280)(0.000233)(31.7 - 33.05) + (0.710)(0.000233)(31.7 - 33.05)\Big]$$

$$+ (0.45)(0.000233)(-22.4 - 33.05)$$

$$= -0.006896$$

Substituting into the $\Delta x_{n.p._1}$ denominator:

$$C_{L_{\alpha_{WB}}} + \sum_{i=1}^{N_I} \sum_{j=1}^{n_{s_i}} K_{S_{ij}} C_{L_{\alpha_{S_{ij}}}} = 0.060 + 2\,[(-0.035)(0.000233) + (0.28)(0.000233)$$

$$+ (0.710)(0.000233)] + (0.45)(0.000233)$$

$$= 0.06055$$

Solution:

$$\Delta x_{n.p._1} = \frac{\text{Numerator}}{\text{Denominator}} = \frac{-0.006896}{0.06055} = -0.114 \text{ in.}$$

The calculated values of $\Delta x_{n.p._1}$ are summed with $\Delta x_{n.p._2}$ and $\Delta x_{n.p._3}$ (computed in Sections 3.3.2 and 3.3.3, respectively) in the Sample Problem of Section 3.3.4 to obtain the total shift in neutral point.

B. TRANSONIC

The method presented in Paragraph A of this section is also valid in the transonic speed range. The expected accuracy of the method is less than that in the subsonic speed range.

C. SUPERSONIC

The method presented in Paragraph A of this section is also valid in the supersonic speed range up to a Mach number of 1.6 to 2.0 as indicated in Table 3.3-A. The maximum Mach number provided in the figures should indicate the level to which the method is substantiated. Caution should be used when extrapolating the data beyond the Mach range provided in the figures.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer. McDonnell Douglas Corporation Rept. DAC-67425, 1968. (U)

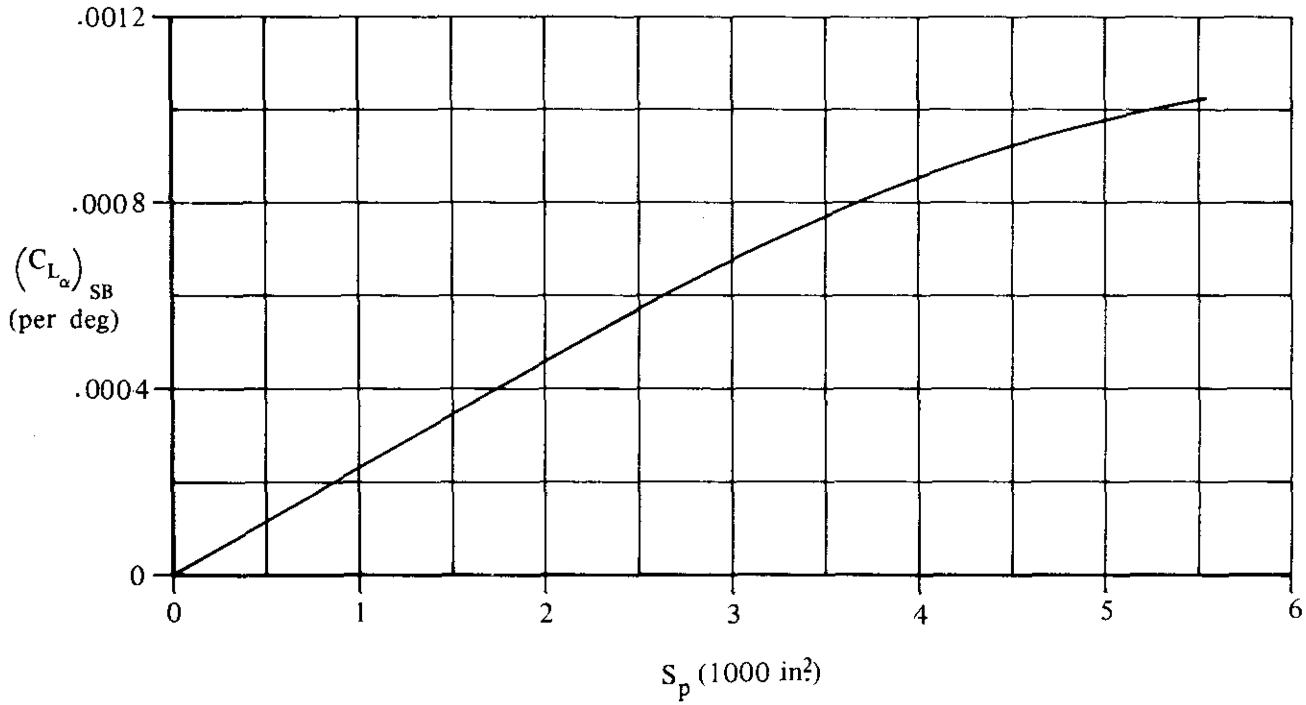


FIGURE 3.3.1-16 STORE-BODY LIFT-CURVE SLOPE

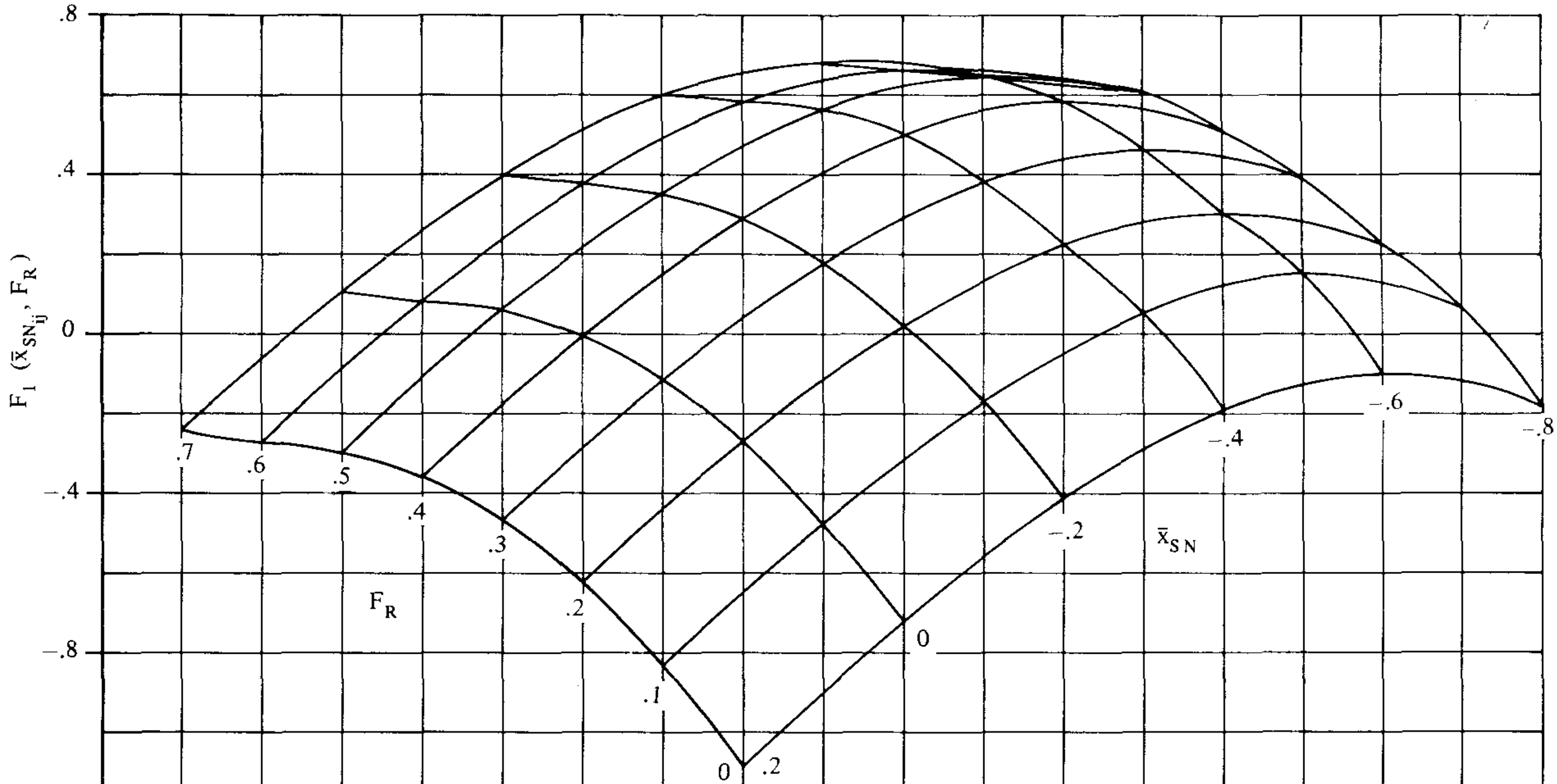


FIGURE 3.3.1-17 STORE LONGITUDINAL-PLACEMENT AND FIN-AREA-RATIO PARAMETER FOR WING-PYLON-MOUNTED SINGLE STORES

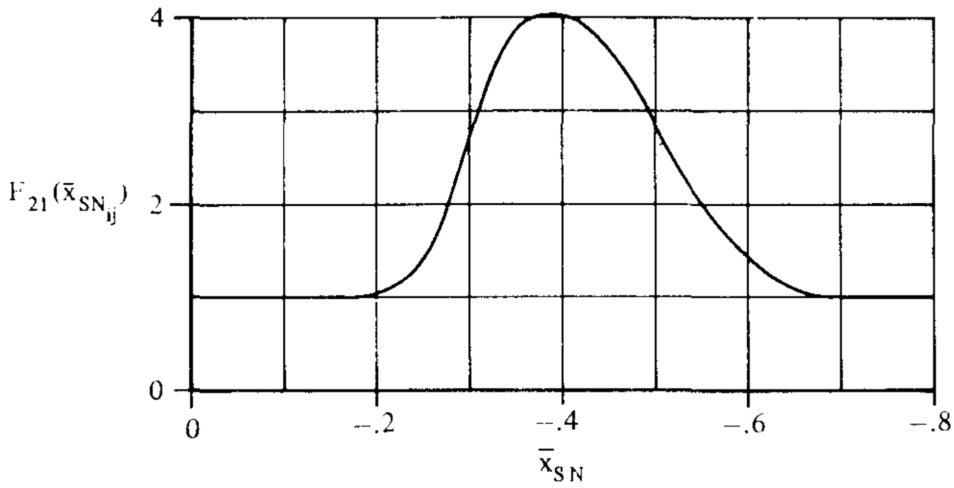


FIGURE 3.3.1-18a STORE LONGITUDINAL-PLACEMENT FACTOR FOR WING-PYLON-MOUNTED SINGLE STORES

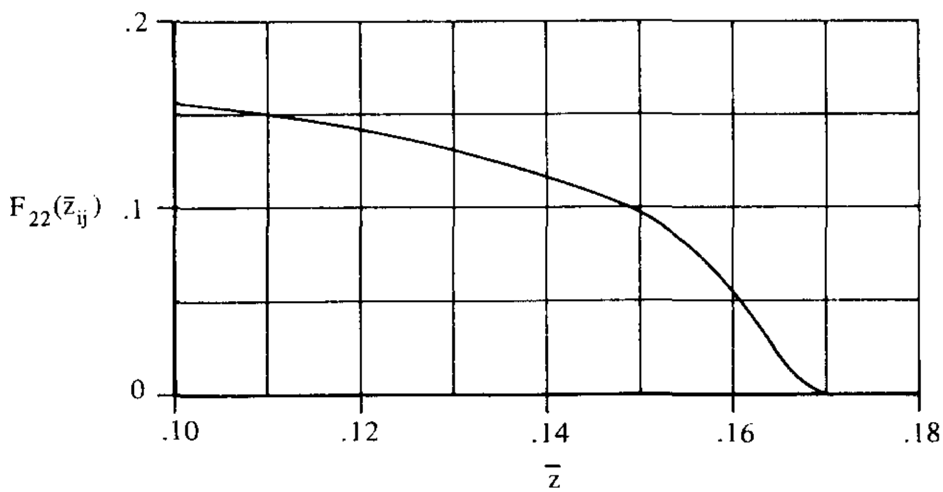


FIGURE 3.1.1-18b STORE VERTICAL-PLACEMENT FACTOR FOR WING-PYLON MOUNTED SINGLE STORES

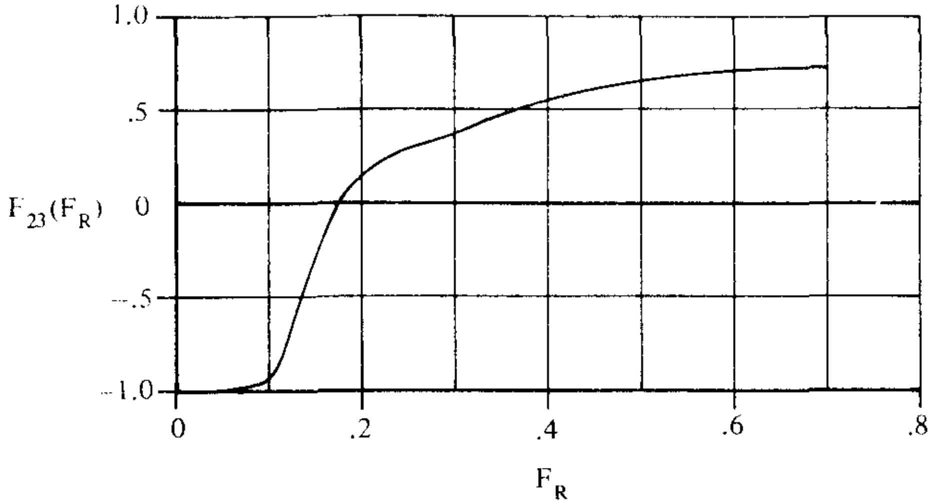


FIGURE 3.3.1-19a STORE-FIN AREA-RATIO FACTOR FOR WING-PLYON-MOUNTED SINGLE STORES

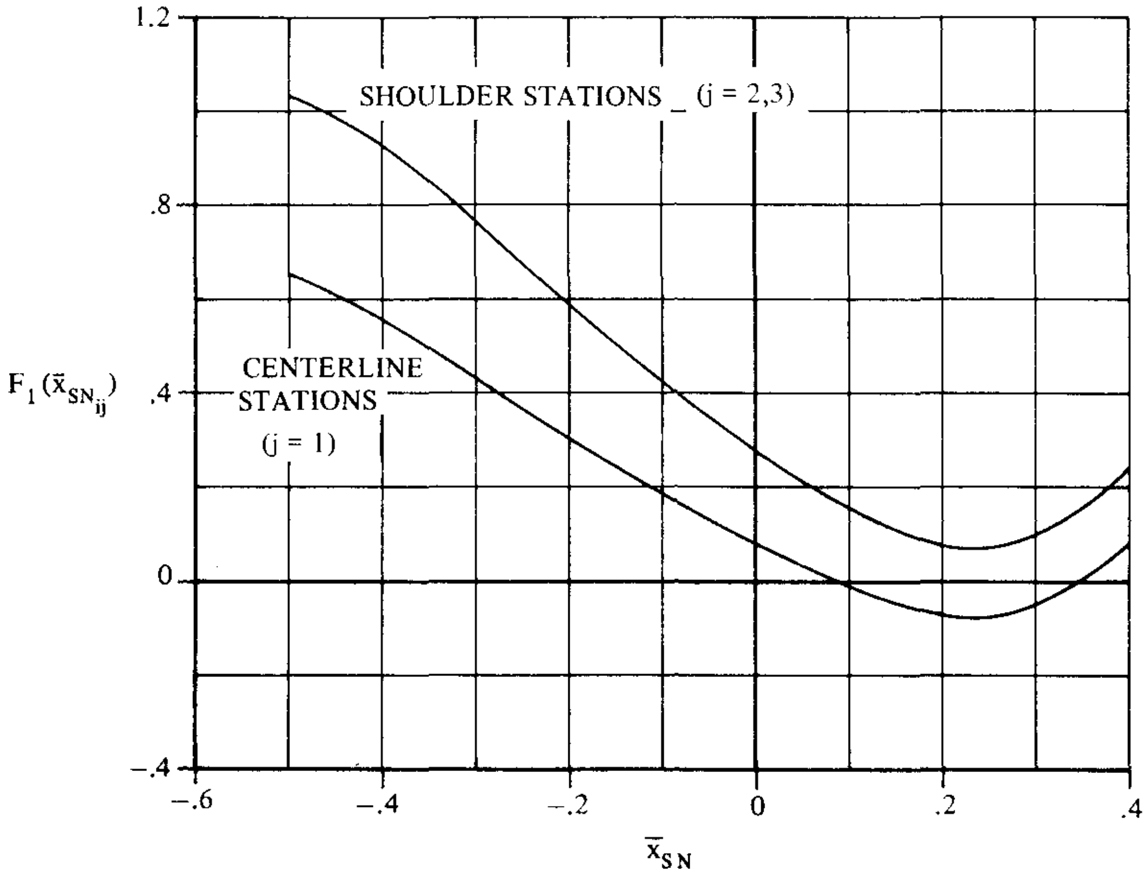


FIGURE 3.3.1-19b STORE LONGITUDINAL-PLACEMENT PARAMETER FOR TER CARRIAGE

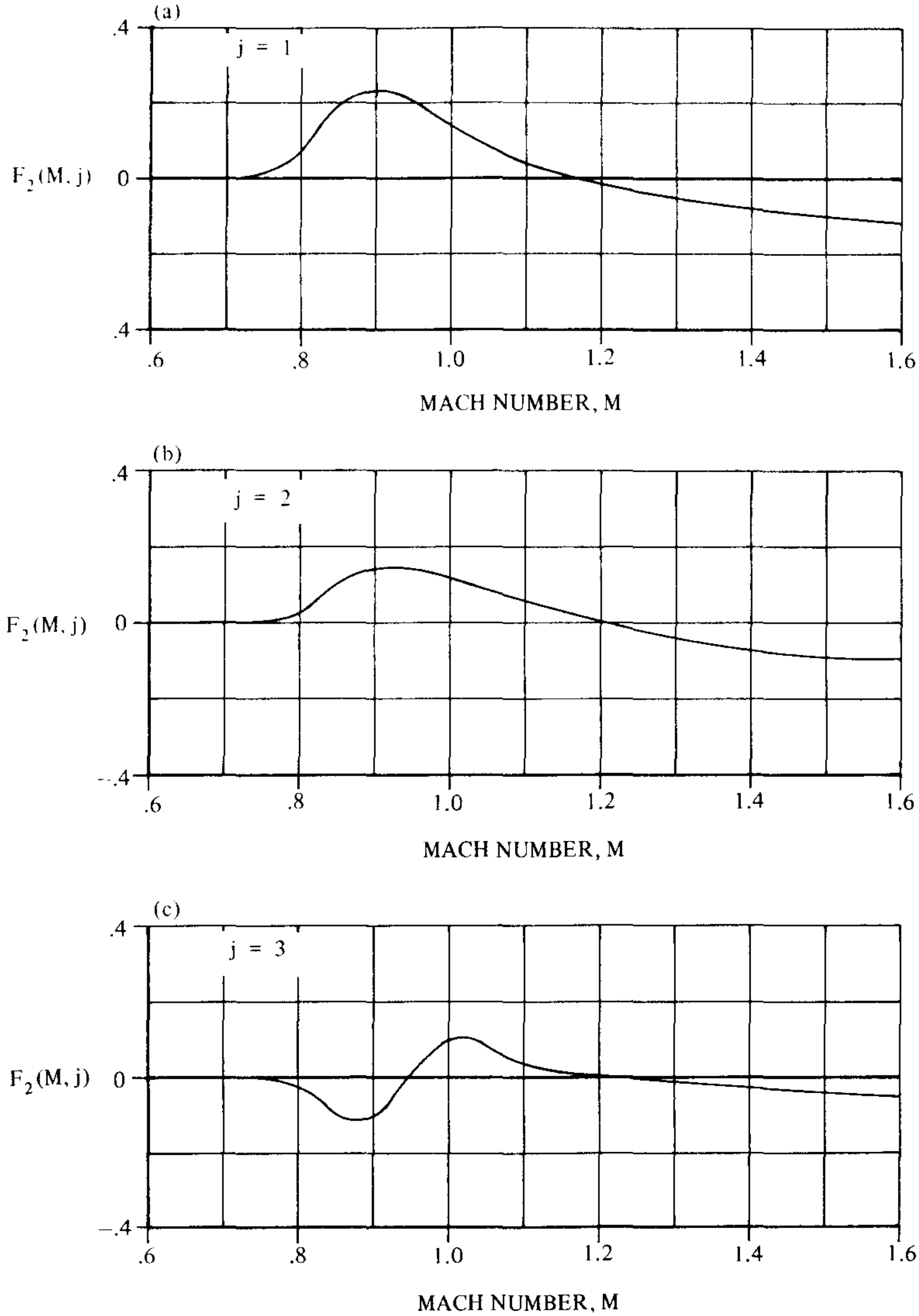


FIGURE 3.3.1-20 TER MACH AND STORE-STATION EFFECT PARAMETER

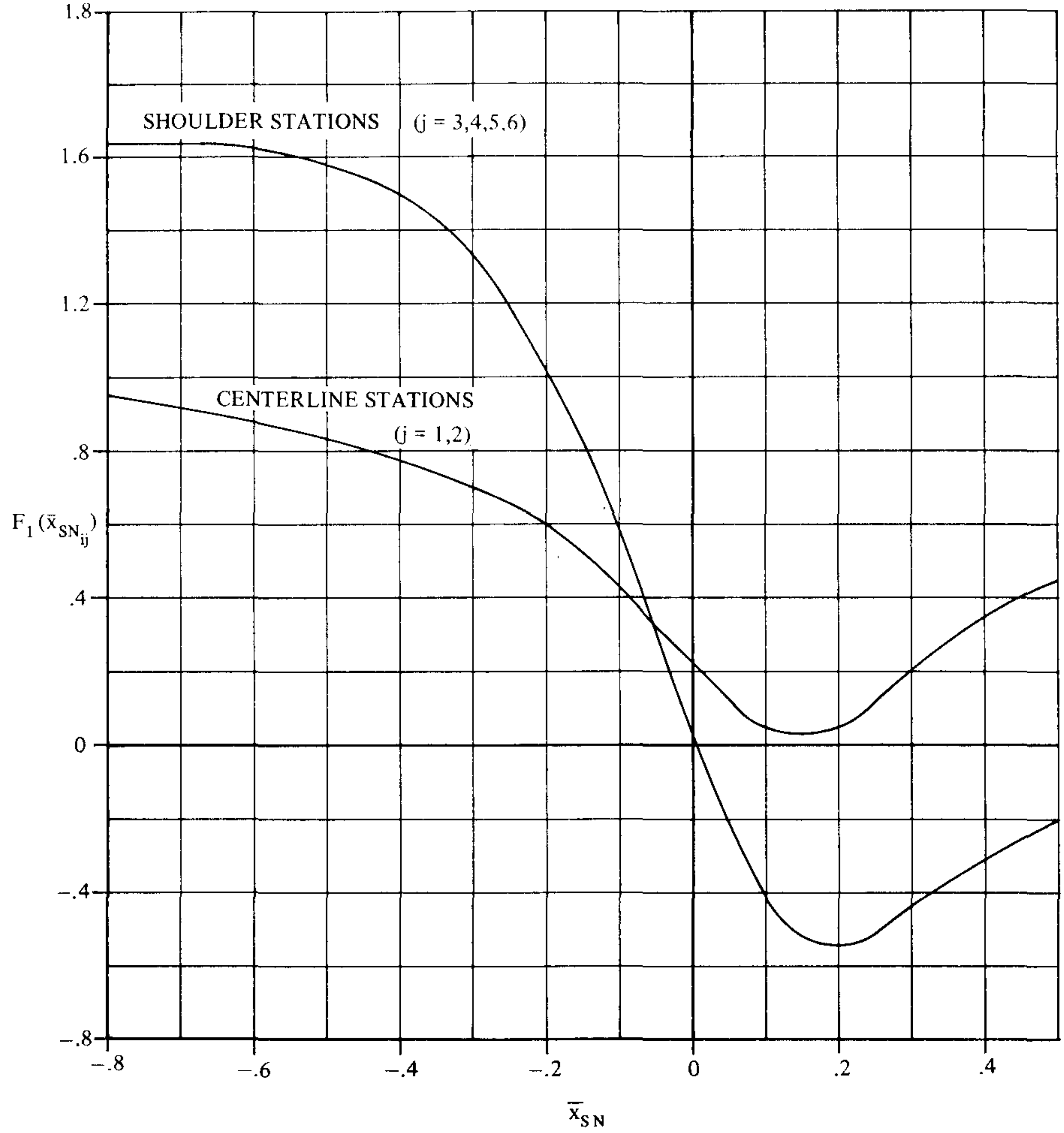


FIGURE 3.3.1-21 STORE LONGITUDINAL-PLACEMENT PARAMETER FOR MER CARRIAGE

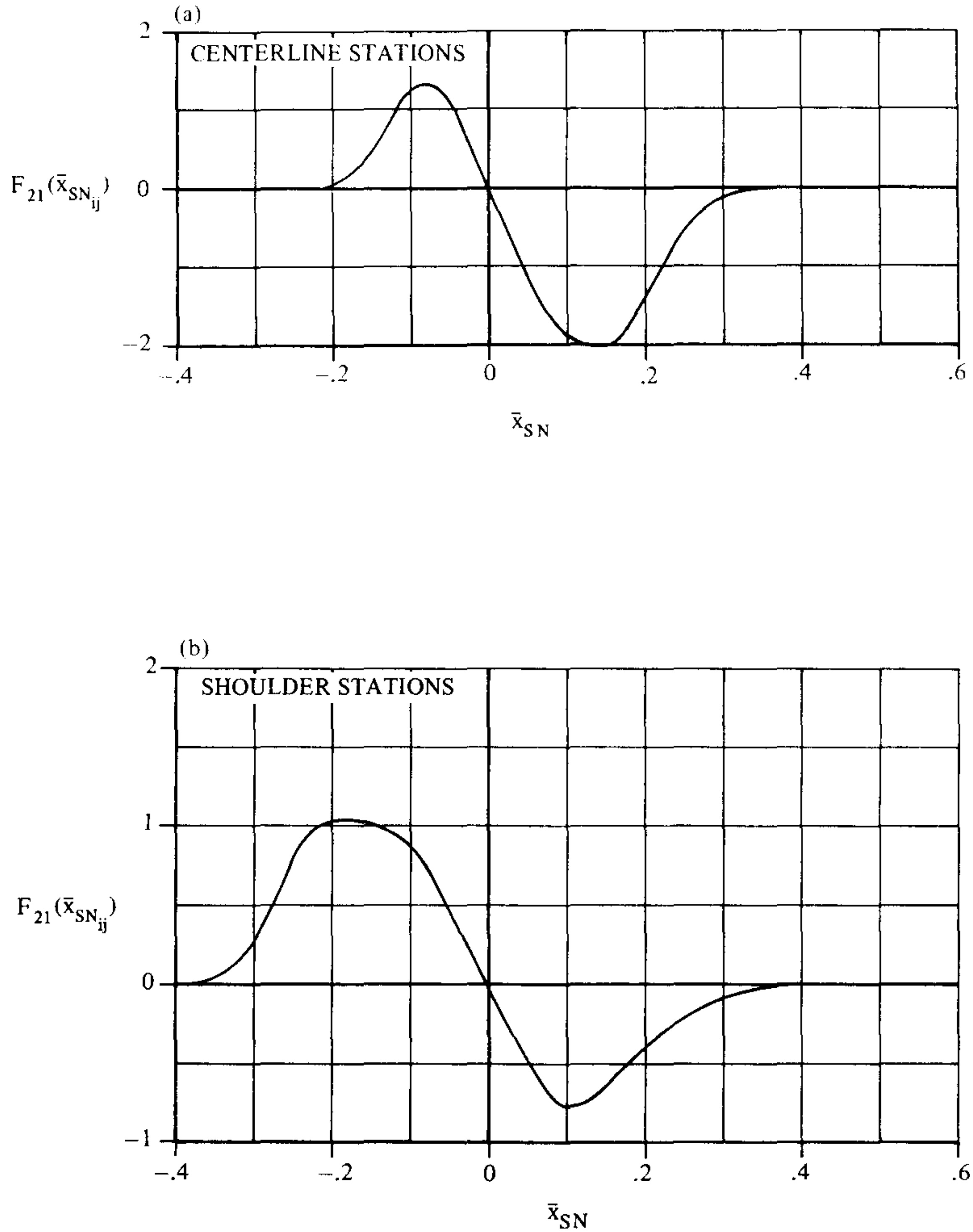


FIGURE 3.3.1-22 STORE LONGITUDINAL-PLACEMENT FACTOR FOR MER CARRIAGE

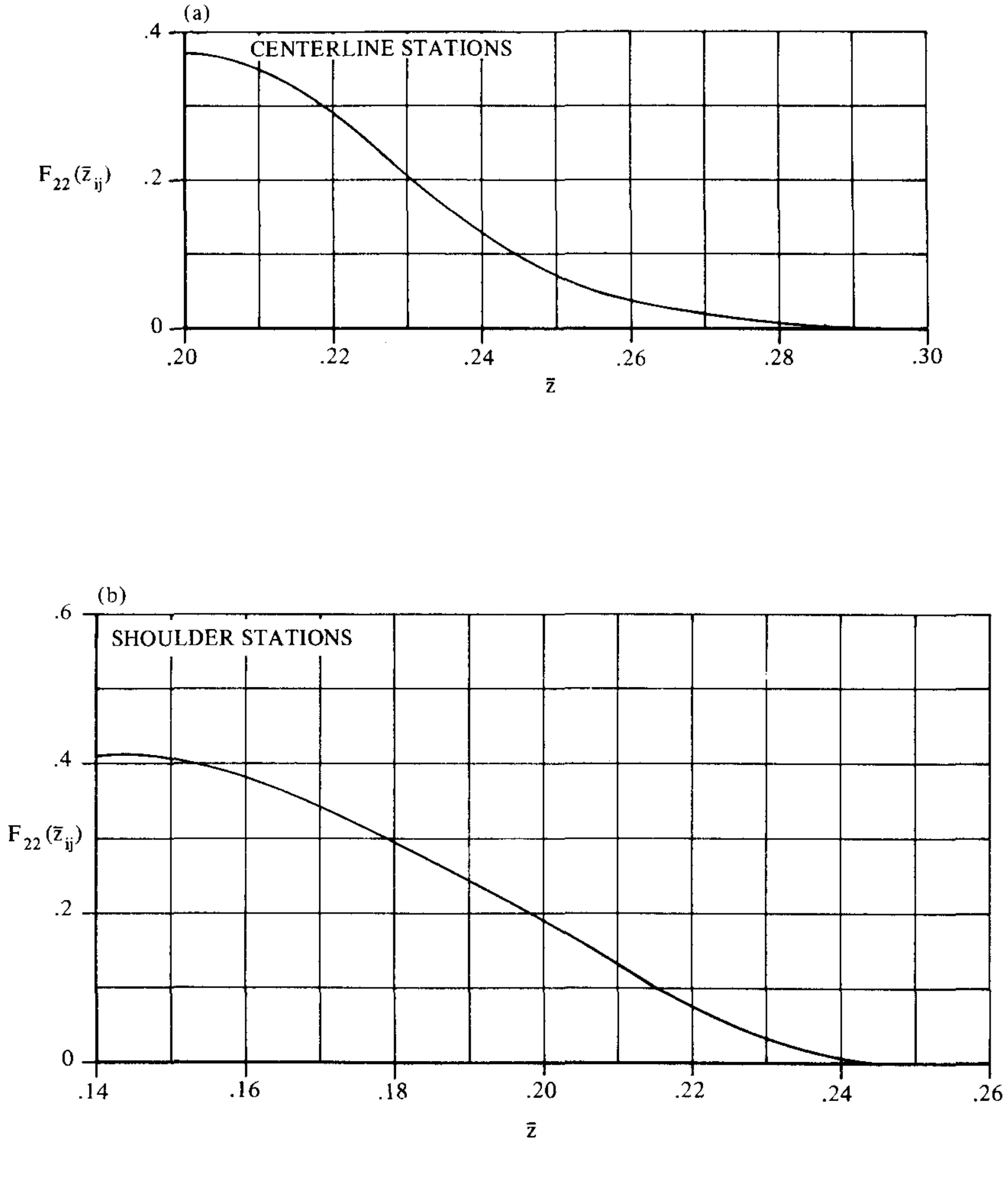
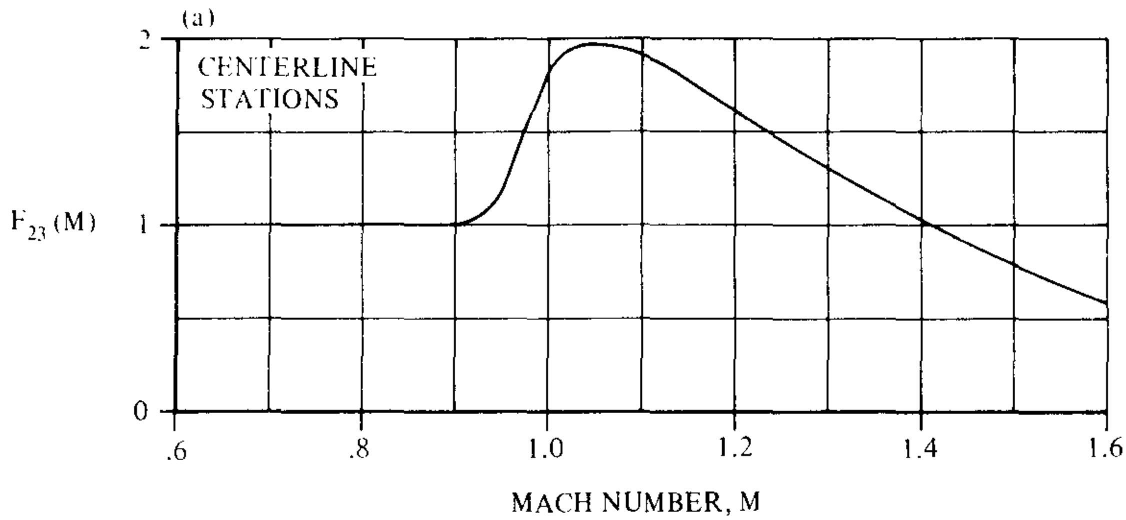


FIGURE 3.3.1-23 STORE VERTICAL-PLACEMENT FACTOR FOR MER CARRIAGE



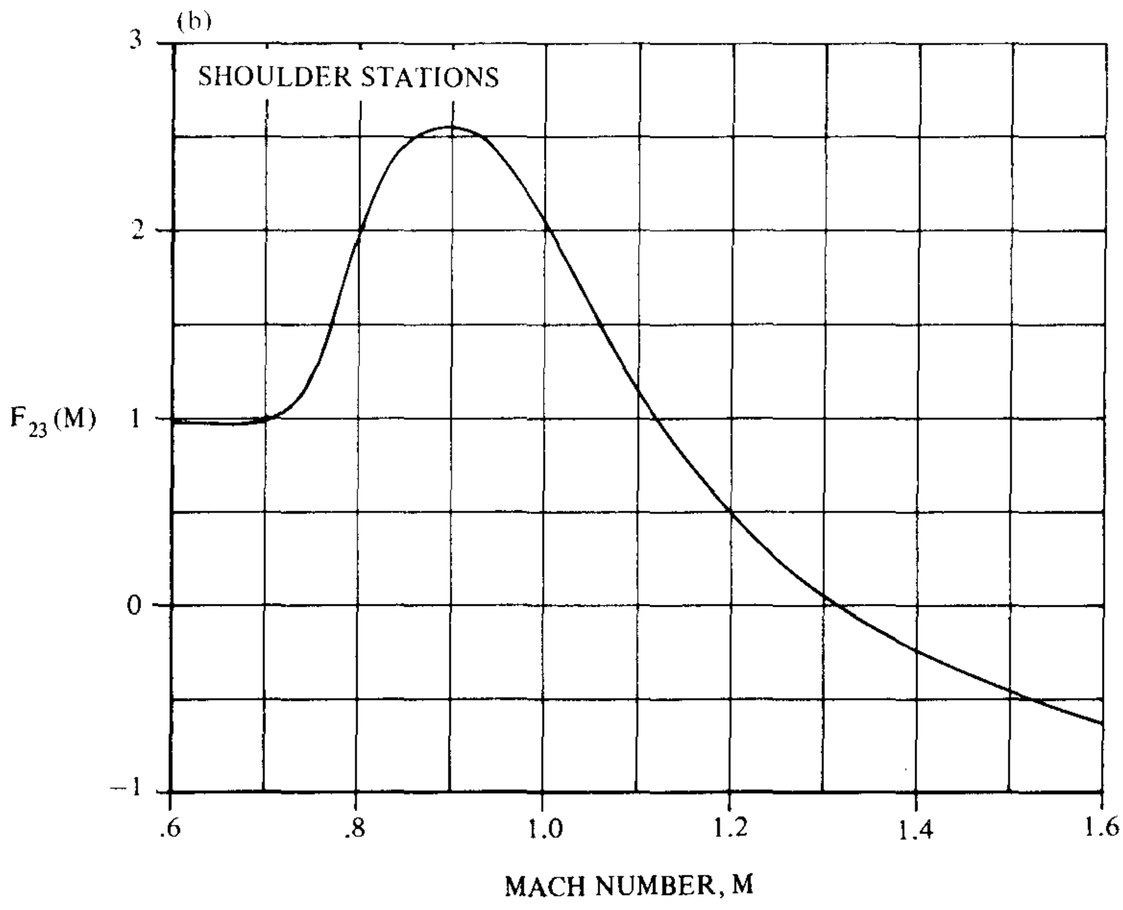


FIGURE 3.3.1-24 MACH-EFFECT FACTOR FOR MER CARRIAGE

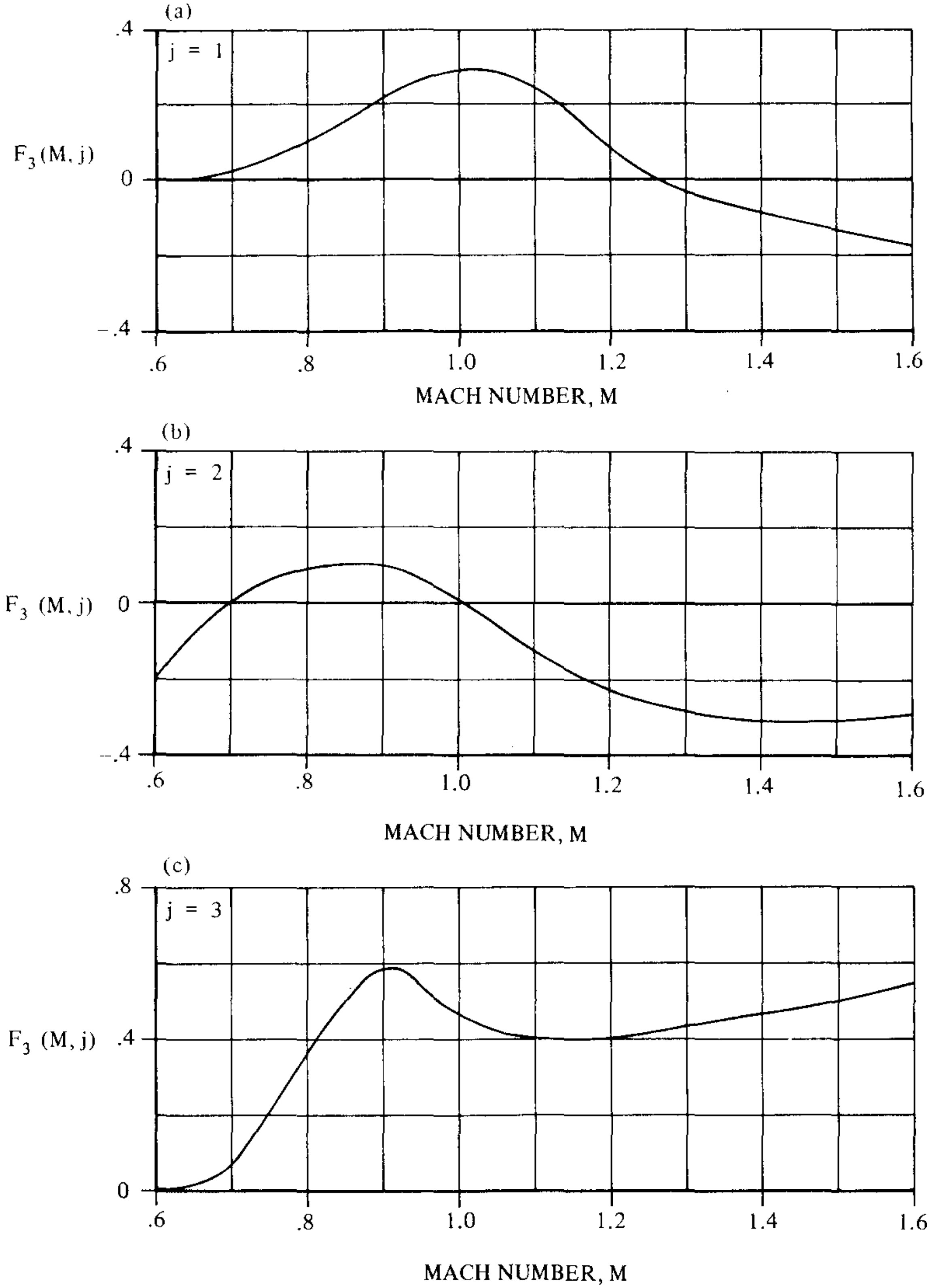
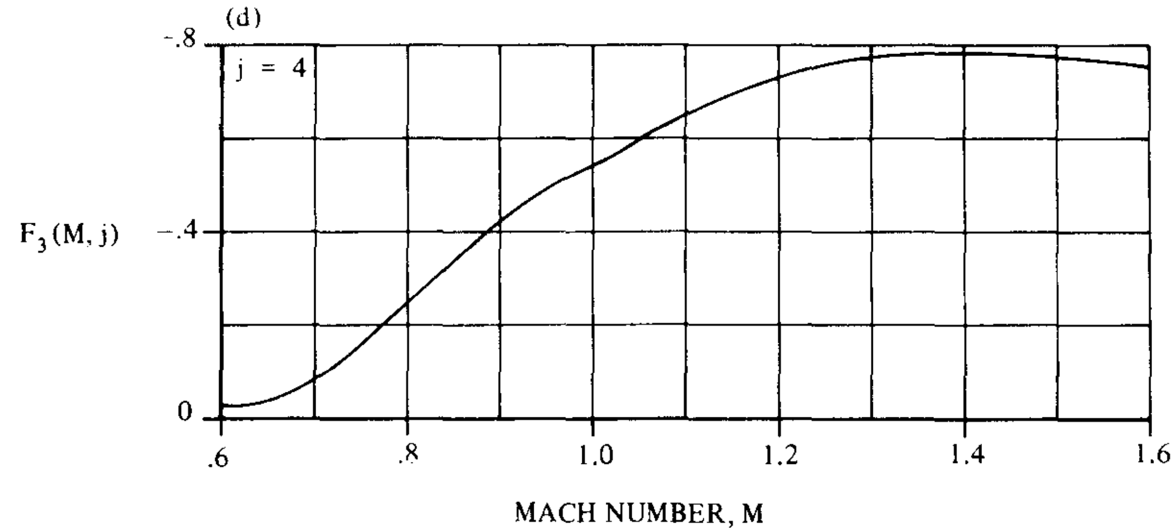
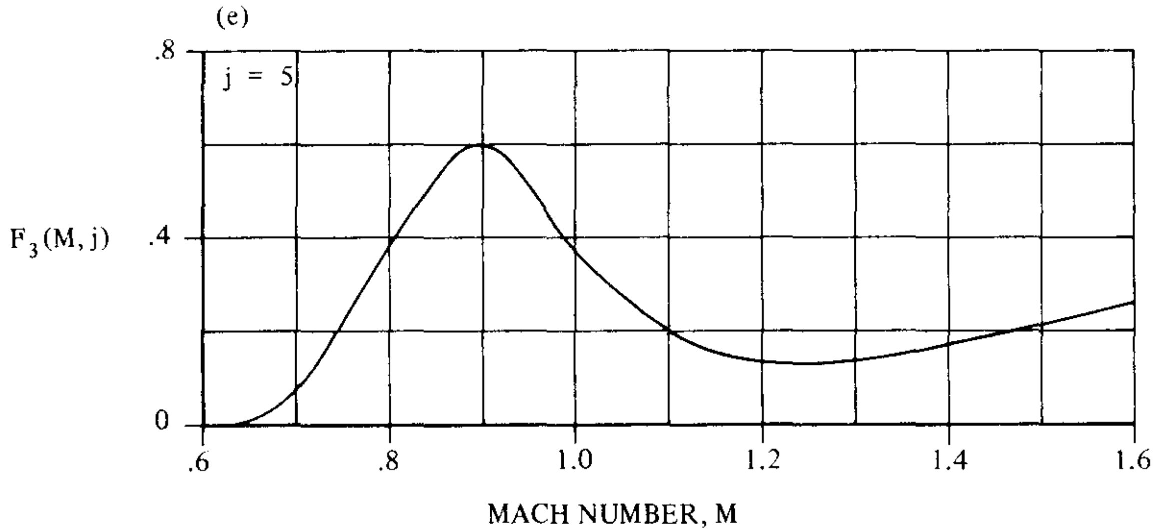


FIGURE 3.3.1-25 MER MACH AND STORE-STATION EFFECT PARAMETER





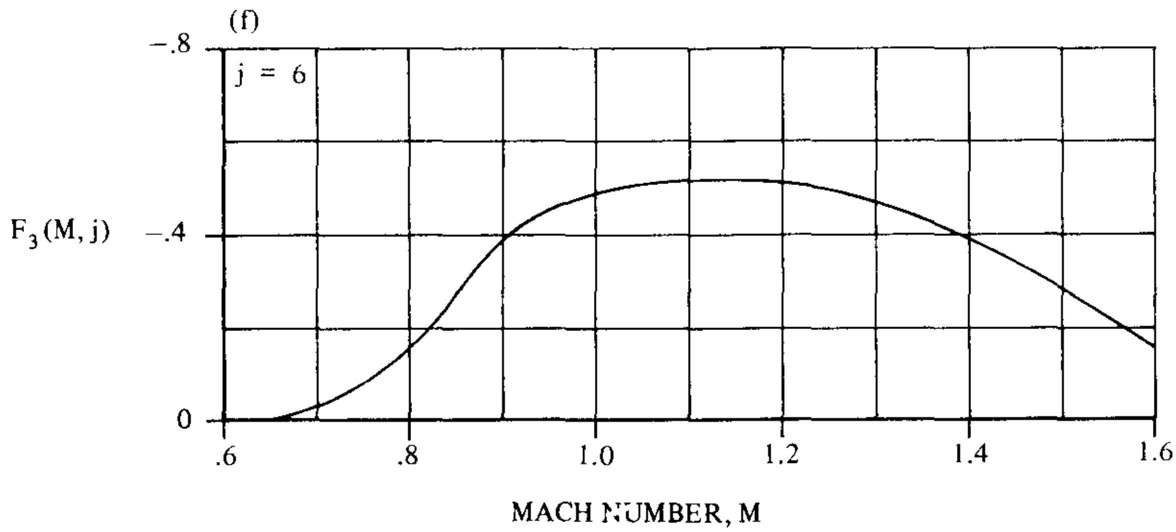


FIGURE 3.3.1-25 (CONTD)

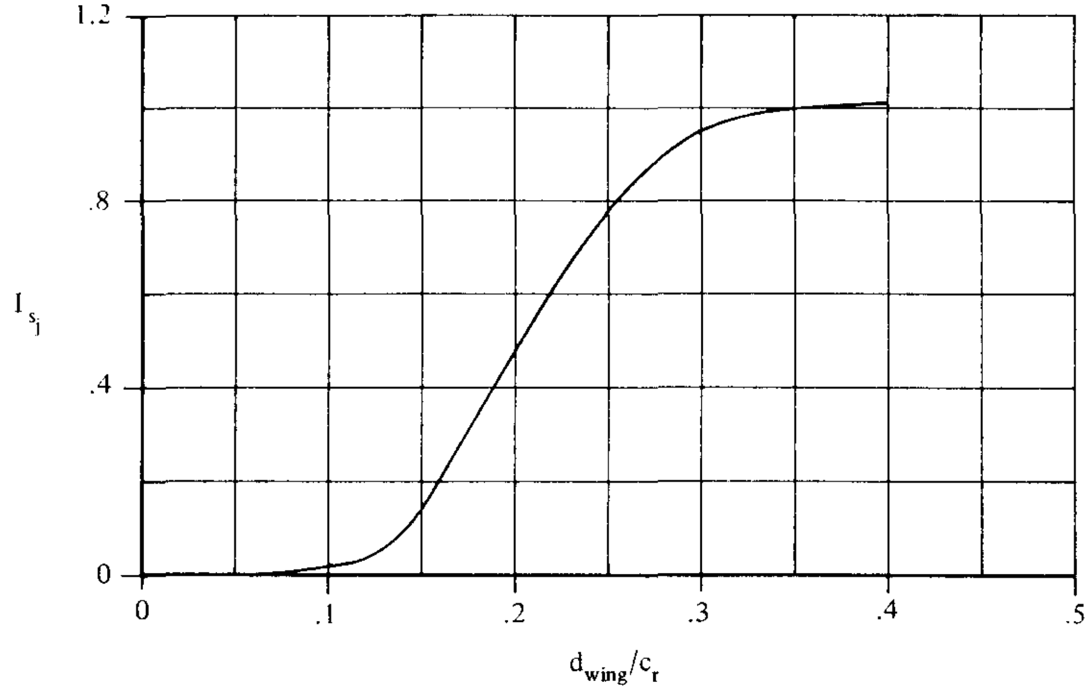


FIGURE 3.3.1-27a MER INSTALLATION NEUTRAL-POINT CORRELATION FACTOR

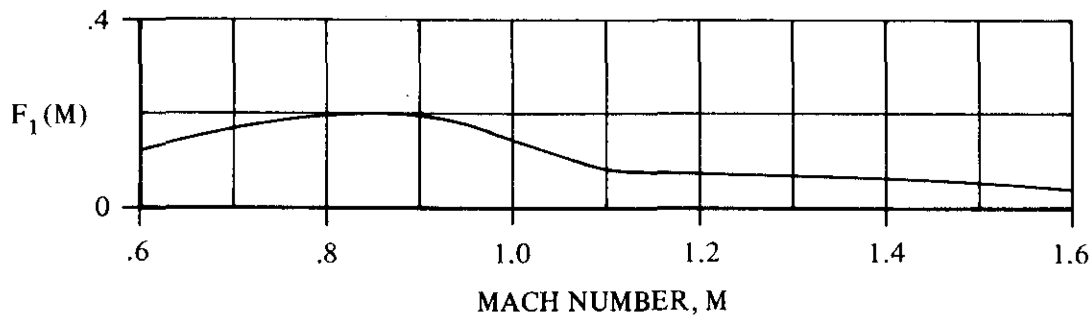


FIGURE 3.3.1-27b MER MACH-EFFECT FACTOR FOR FUSELAGE-TANGENT-MOUNTED INSTALLATIONS

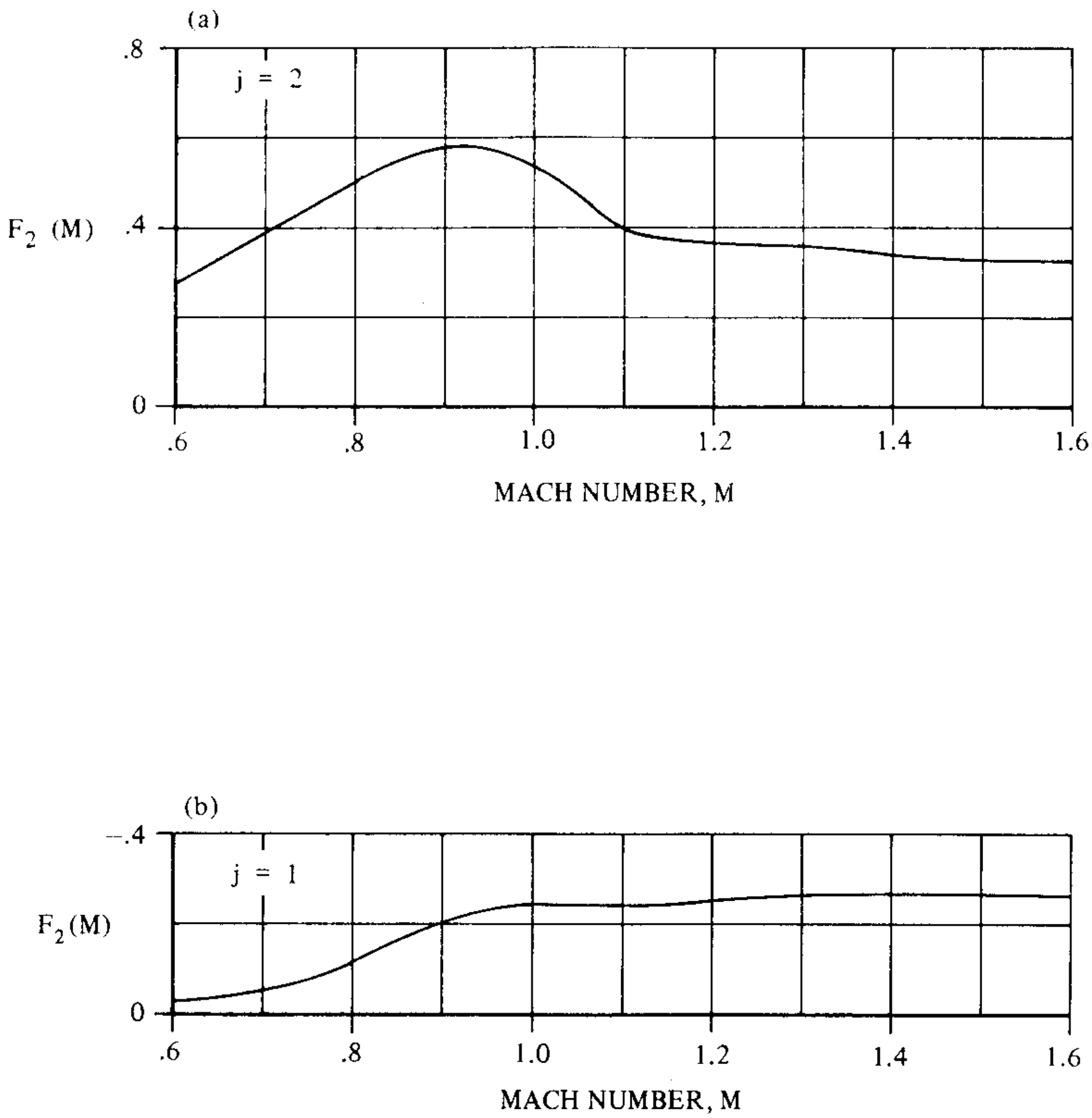
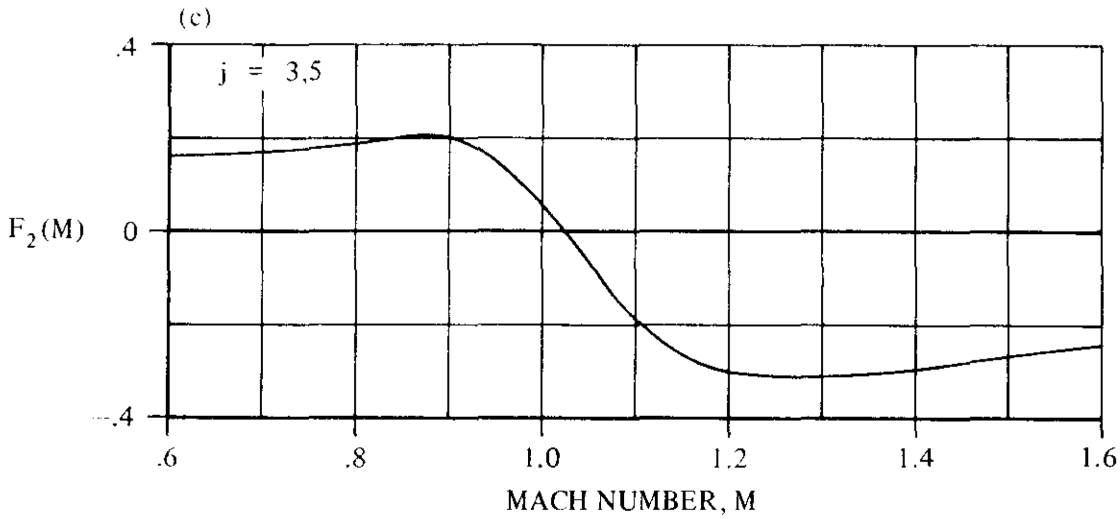


FIGURE 3.3.1-28 MER MACH AND STORE-STATION EFFECT PARAMETER FOR FUSELAGE-TANGENT-MOUNTED INSTALLATIONS



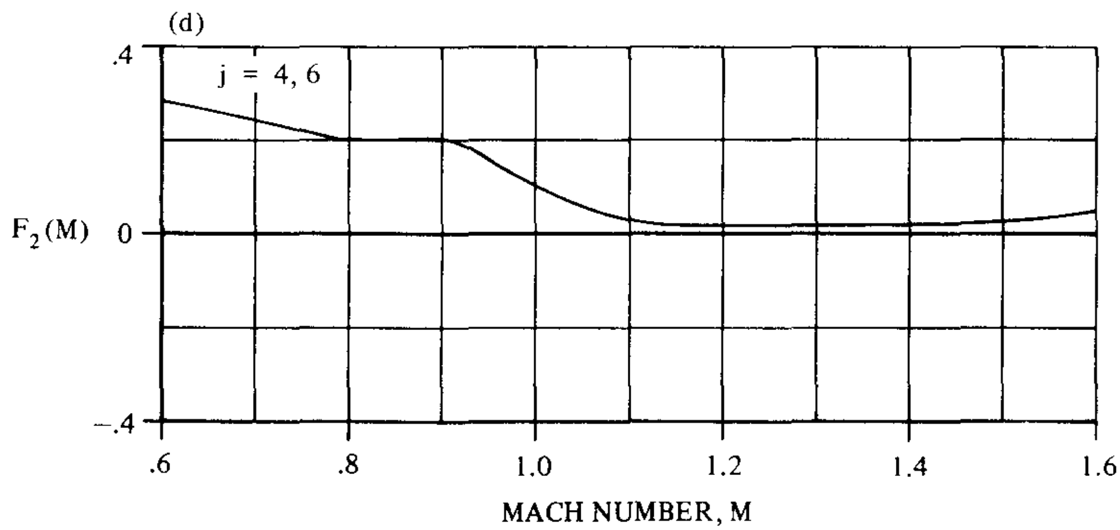


FIGURE 3.3.1-28 (CONTD)

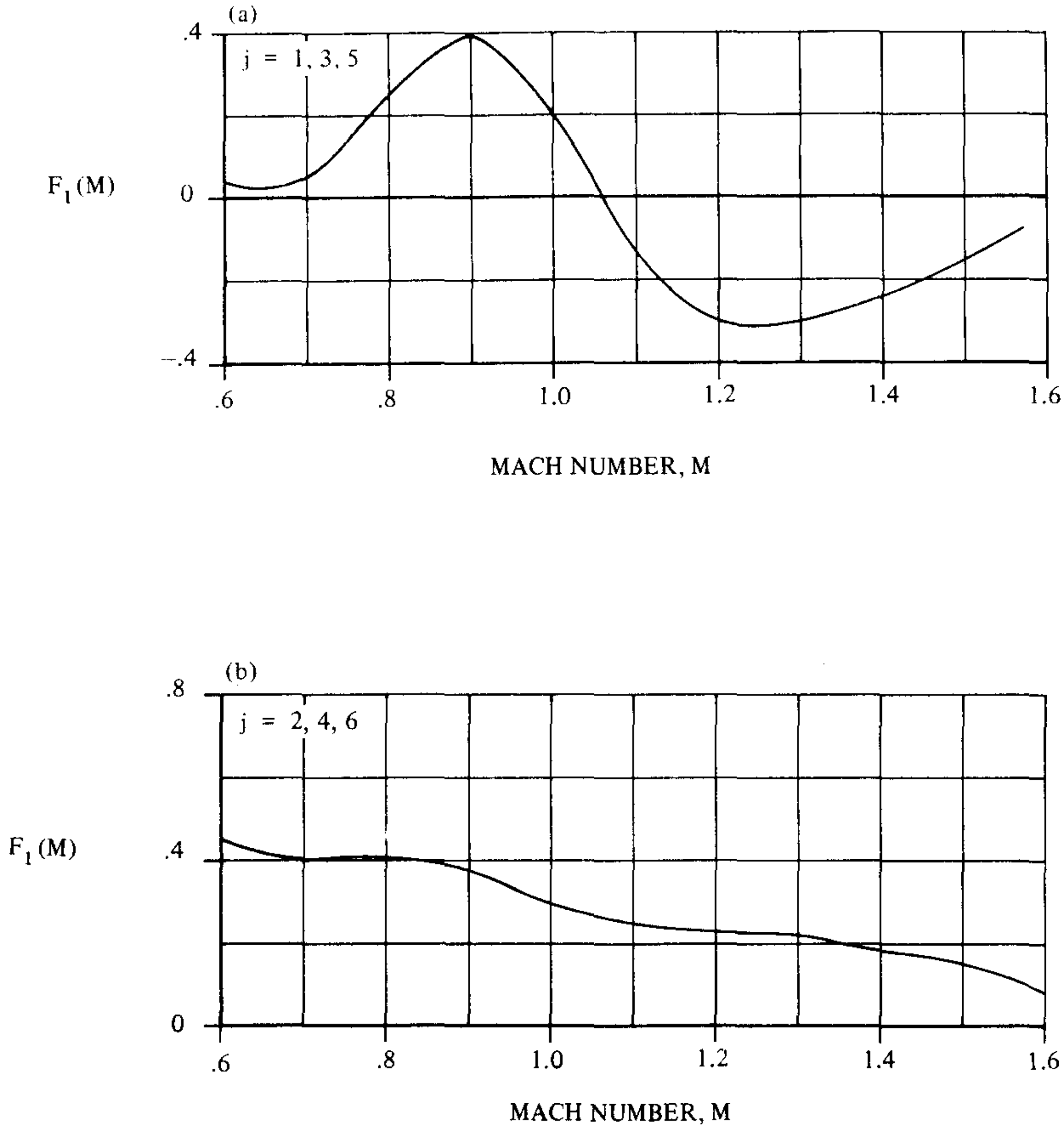


FIGURE 3.3.1-30 MER MACH EFFECT FACTOR FOR FUSELAGE-PYLON-MOUNTED INSTALLATIONS

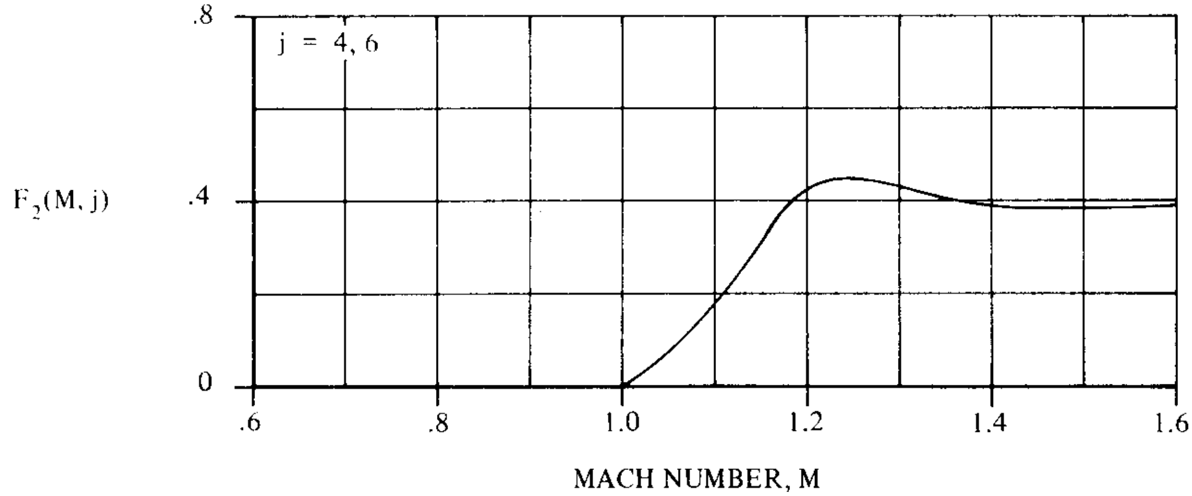


FIGURE 3.3.1-31 MER MACH AND STORE-STATION EFFECT PARAMETER FOR FUSELAGE-PYLON-MOUNTED INSTALLATIONS

3.3.2 NEUTRAL-POINT SHIFT DUE TO INTERFERENCE EFFECTS ON WING FLOW FIELD

A method is presented in this section for estimating the neutral-point shift due to interference effects on the wing flow field from external-store installations. The method predicts a neutral-point shift due to all installations (armament stations) on the aircraft.

The Datcom Method is taken from Reference 1 and is empirical in nature. The method is applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The limitations on configuration and Mach-number range are summarized in Table 3.3-A. Additional limitations and assumptions pertaining to the method are listed below:

1. The method is not applicable to wing-tip or wing-tangent-mounted stores.

2. The method has been verified for the Mach-number range given in Table 3.3-A. Caution should be used in extrapolating the empirical curves beyond the given Mach-number range.

3. The method has not been verified for configurations in which flaps, slats or other flow-disrupting devices are deployed.

4. The method gives the best results for angle-of-attack range from 0 to 8°, although the method can be used for higher angles of attack.

5. The data base used in deriving the method relied heavily on swept-wing tactical-combat-aircraft wind-tunnel data.

6. The method is applicable for sideslip angles less than 4°.

7. Fuselage-mounted installations must be located on the fuselage centerline.

8. The method is not applicable to empty multiple racks.

9. The effect of empty pylons on neutral point is considered to be negligible.

The effect due to a pair of symmetrical installations can be computed by doubling the effect of one side.

A. SUBSONIC

DATCOM METHOD

The neutral-point shift in inches, positive for aft shift, due to wing flow-field interference effects is given by

$$\Delta x_{n.p._2} = \left(\frac{S_W}{N_I}\right)\left(\sum_{i=1}^{N_I} \sum_{j=1}^{n_{s_i}} C_{L_{\alpha_{S_{ij}}}}\right)\left[\sum_{i=1}^{N_I} \delta S_i \left(\Delta x'_{n.p._2} + K_1 K_2 K_3\right)_i\right] \qquad \text{3.3.2-a}$$

where

S_W is the wing reference area (ft^2).

N_I is the total number of store installations on the aircraft.

n_{s_i} is the number of store stations on installation i (including empty stations).

$C_{L_{\alpha_{S_{ij}}}}$ is the free-stream lift-curve slope of store j on installation i (per deg) given by Equation 3.3.1-b.

δ_{S_i} is a parameter related to configuration:

1. For Wing-Pylon Single Carriage:

$$\delta_{S_i} = 20 \qquad 3.3.2\text{-b}$$

2. For Wing-Pylon MER and TER Carriage, and Centerline Single Carriage:

$$\delta_{S_i} = 10 \qquad 3.3.2\text{-c}$$

3. For Fuselage-Centerline MER Carriage:

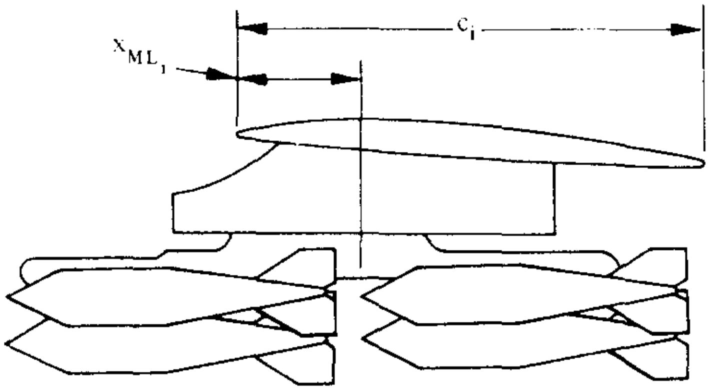
$$\delta_{S_i} = 17.4 \qquad 3.3.2\text{-d}$$

$\Delta x'_{n.p._2}$ is a neutral-point basic-interference-effect term obtained from Figures 3.3.2-6a through -6d as a function of configuration and Mach number.

K_1 is a span-location-correction factor obtained from Figures 3.3.2- 8a through - 8c as a function of configuration and $\frac{y_i}{b_W/2}$, where y_i is the wing semispan location of installation i and b_W is the wing span.

Note: For fuselage-mounted installations, $K_1 = 1$.

K_2 is a longitudinal-correction factor obtained from Figure 3.3.2-9a through -9d as a function of x_{ML_i}/c_i, where x_{ML_i} is the distance (in.) from the local wing leading edge to the point midway between the pylon mounting lugs on installation i (positive for the pylon mid-lug point aft of the local wing leading edge), and c_i is the local wing chord (in.) at the semispan location of store installation i. (See Sketch (a).)



SKETCH (a)

K_3 is a Mach-number-correction factor obtained from Figures 3.3.2-11a through -11d as a function of configuration and Mach number.

Sample Problem

Given: A swept-wing subsonic-fighter aircraft from Reference 2 described in the Sample Problem of Paragraph A of Section 3.3.1.

Additional Data:

$C_{L_{\alpha_{S_{ij}}}}$ = 0.000233 per deg (Sample Problem, Paragraph A, Section 3.3.1)

$M = 0.6$

$b_W/2 = 165$ in.

Installation No., i	1,5	2,4	3
x_{ML_i}/c_i	0.204	0.180	0.445
y_i	113.75	78.8	0

Compute:

$$\frac{S_W}{N_I} = \frac{260}{5} = 52.0 \qquad \text{(first term of Equation 3.3.2-a)}$$

Since all stores are identical and there are a total of 11 stores,

$$\sum_{i=1}^{N_I} \sum_{j=1}^{n_{s_i}} C_{L_{\alpha_{S_{ij}}}} = 11\, C_{L_{\alpha_{S_{ij}}}} \qquad \text{(second term of Equation 3.3.2-a)}$$

$$= (11)(0.000233)$$
$$= 0.00256 \text{ per deg}$$

Since the wing installations 1 and 2 are symmetrical, only one side is calculated and the result multiplied by 2.

δ_{S_1} = 20 (Equation 3.3.2-b)

δ_{S_1} = 10 (Equation 3.3.2-c)

δ_{S_3} = 17.4 (Equation 3.3.2-d)

For Installation 1 (Wing-Pylon-Mounted Single Store)

$\Delta x'_{n.p._2}$ = -0.03 (Figure 3.3.2-6a)

$y_i/(b_W/2)$ = 0.689

K_1 = 0 (Figure 3.3.2-8a)

K_2 = 0 (Figure 3.3.2-9a)

K_3 = -0.39 (Figure 3.3.2-11a)

For Installation 2 (Wing-Pylon-Mounted TER)

$\Delta x'_{n.p._2}$ = -0.02 (Figure 3.3.2-6b)

$y_i/(b_W/2)$ = 0.478

K_1 = 0 (Figure 3.3.2-8b)

K_2 = 0.37 (Figure 3.3.2-9b)

K_3 = -0.25 (Figure 3.3.2-11b)

For Installation 3 (Fuselage-Centerline-Pylon-Mounted MER)

$\Delta x'_{n.p._2}$ = 0.125 (Figure 3.3.2-6d)

K_1 = 1.0 (Fuselage-mounted installation)

K_2 = 1.0 (Figure 3.3.2-9d)

K_3 = 0 (Figure 3.3.2-11d)

$$\sum_{i=1}^{N_I} \delta_{S_i} \left(\Delta x'_{n.p._2} + K_1 K_2 K_3\right)_i = 2\delta_{S_1} \left(\Delta x'_{n.p._2} + K_1 K_2 K_3\right)_{i=1} \quad \text{(third term of Equation 3.3.2-a)}$$

$$+ 2\delta_{S_2} \left(\Delta x'_{n.p._2} + K_1 K_2 K_3\right)_{i=2}$$

$$+ \delta_{S_3} \left(\Delta x'_{n.p._3} + K_1 K_2 K_3\right)_{i=3}$$

$$= (2)(20)\,[-0.03 + (0)(0)(-0.39)]$$

$$+ (2)(10)[-0.02 + (0)(0.37)(-0.25)]$$

$$+ (17.4)[0.125 + (1.0)(1.0)(0)]$$

$$= 0.575$$

Solution:

$$\Delta x_{n.p._2} = \left(\frac{S_W}{N_I}\right)\left(\sum_{i=1}^{N_I} \sum_{j=1}^{n_{s_i}} C_{L_{\alpha_{S_{ij}}}}\right) \left[\sum_{i=1}^{N_I} \delta_{S_i} \left(\Delta x'_{n.p._2} + K_1 K_2 K_3\right)_i\right] \quad \text{(Equation 3.3.2-a)}$$

$$= (52.0)(0.00256)(0.575) = 0.077 \text{ in.}$$

The calculated value of $\Delta x_{n.p._2}$ is summed with $\Delta x_{n.p._1}$ and $\Delta x_{n.p._3}$ (computed in Sections 3.3.1 and 3.3.3, respectively) in the Sample Problem of Section 3.3.4 to obtain the total shift in neutral point.

B. TRANSONIC

The method presented in Paragraph A of this section is also valid in the transonic speed range. The expected accuracy of the method is less than that in the subsonic speed range.

C. SUPERSONIC

The method presented in Paragraph A of this section is also valid in the supersonic speed range up to a Mach number of 1.6 to 2.0 as indicated in Table 3.3-A. The maximum Mach number provided in the figures should indicate the level to which the method is substantiated. Caution should be used when extrapolating the data beyond the Mach-number range provided in the figures.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer. McDonnell Douglas Corporation Rept. DAC-67425, 1968. (U)

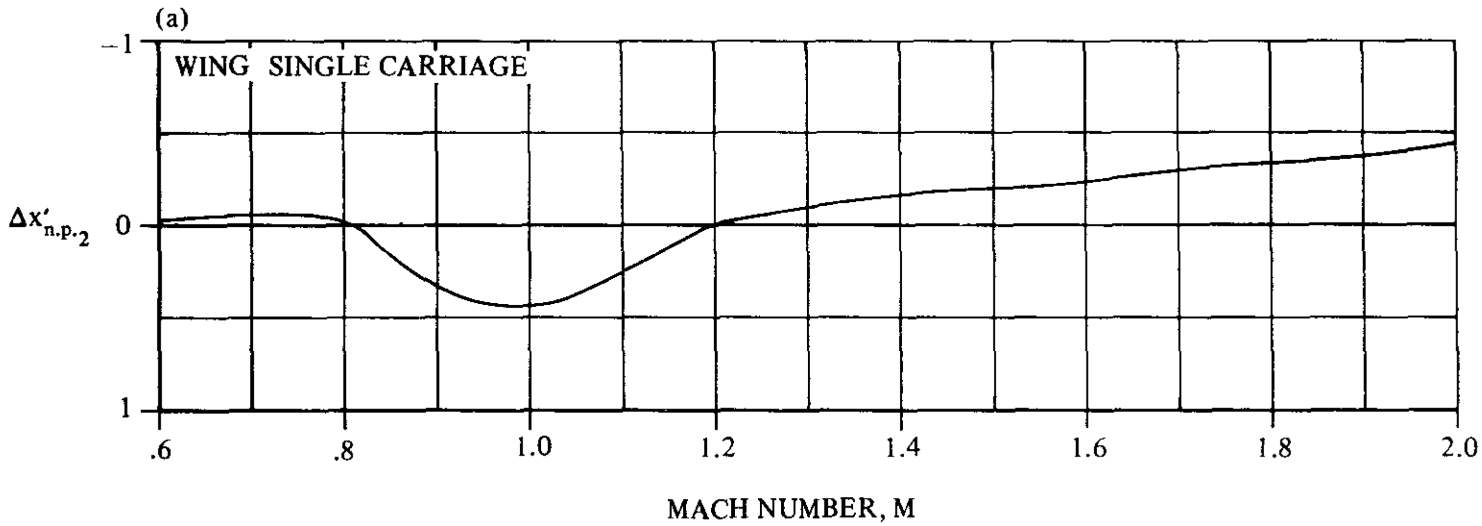


FIGURE 3.3.2-6 NEUTRAL-POINT BASIC-INTERFERENCE-EFFECT TERM

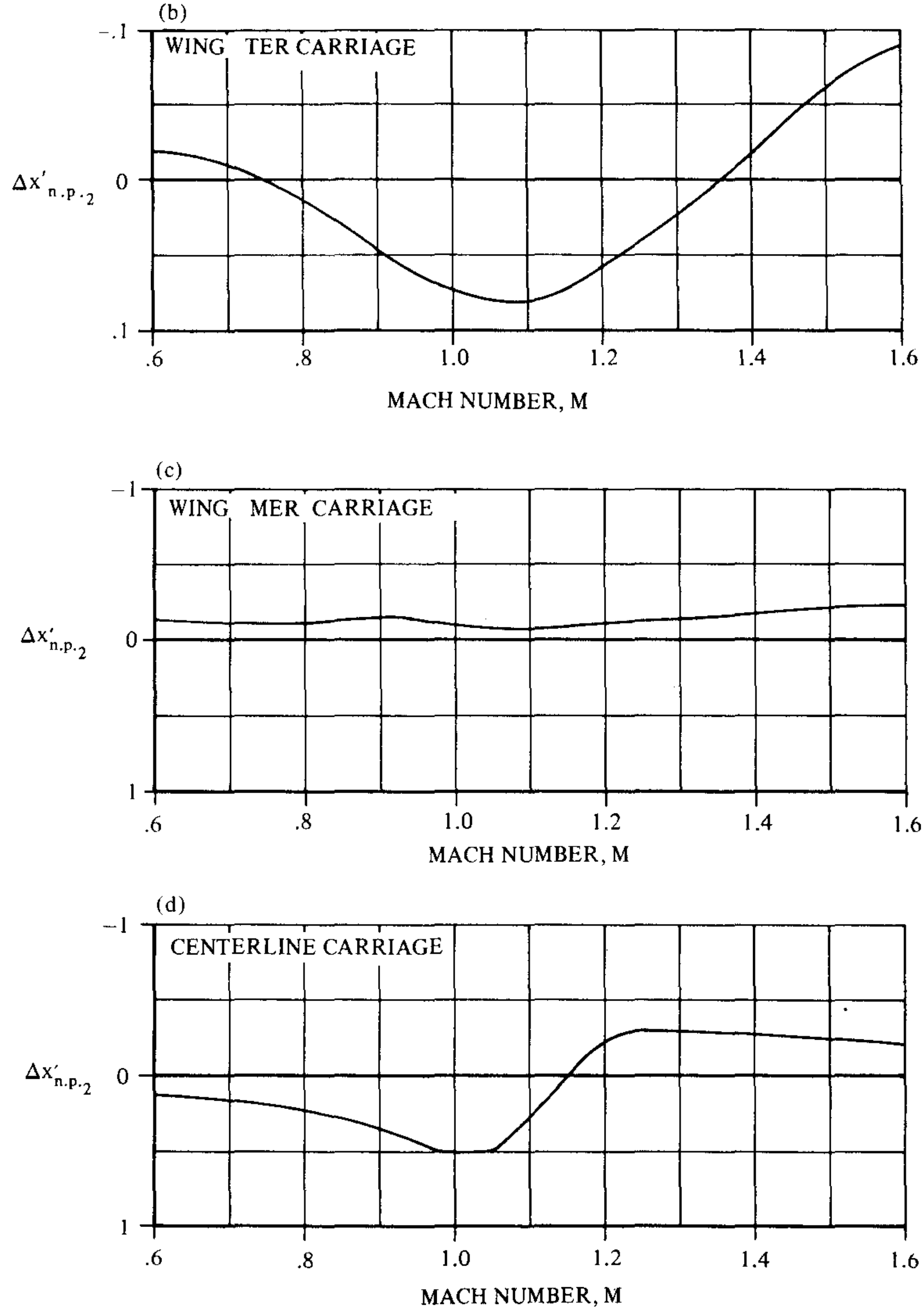


FIGURE 3.3.2- 6 (CONTD)

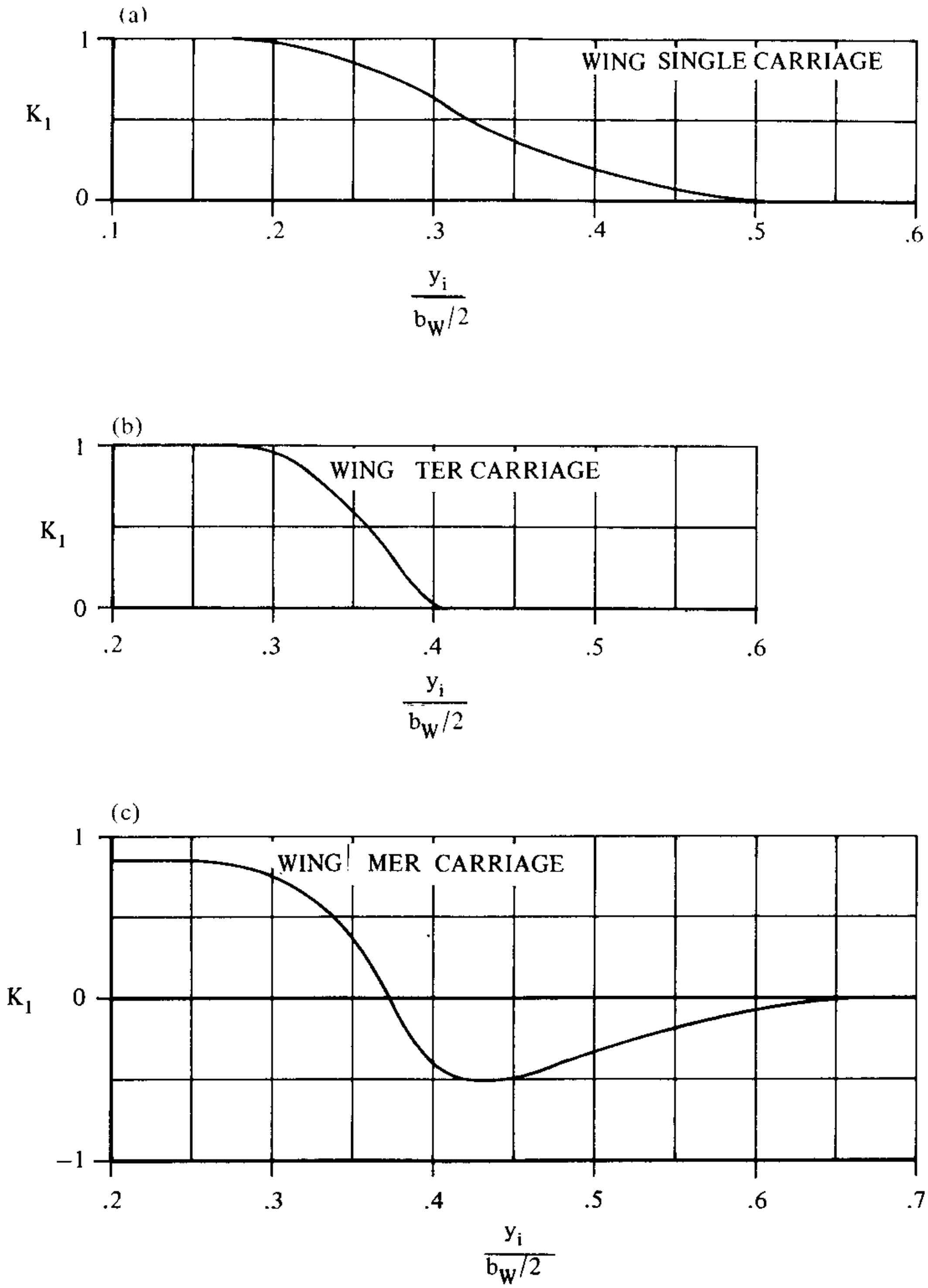


FIGURE 3.3.2-8 NEUTRAL-POINT SPAN-LOCATION-CORRECTION FACTOR

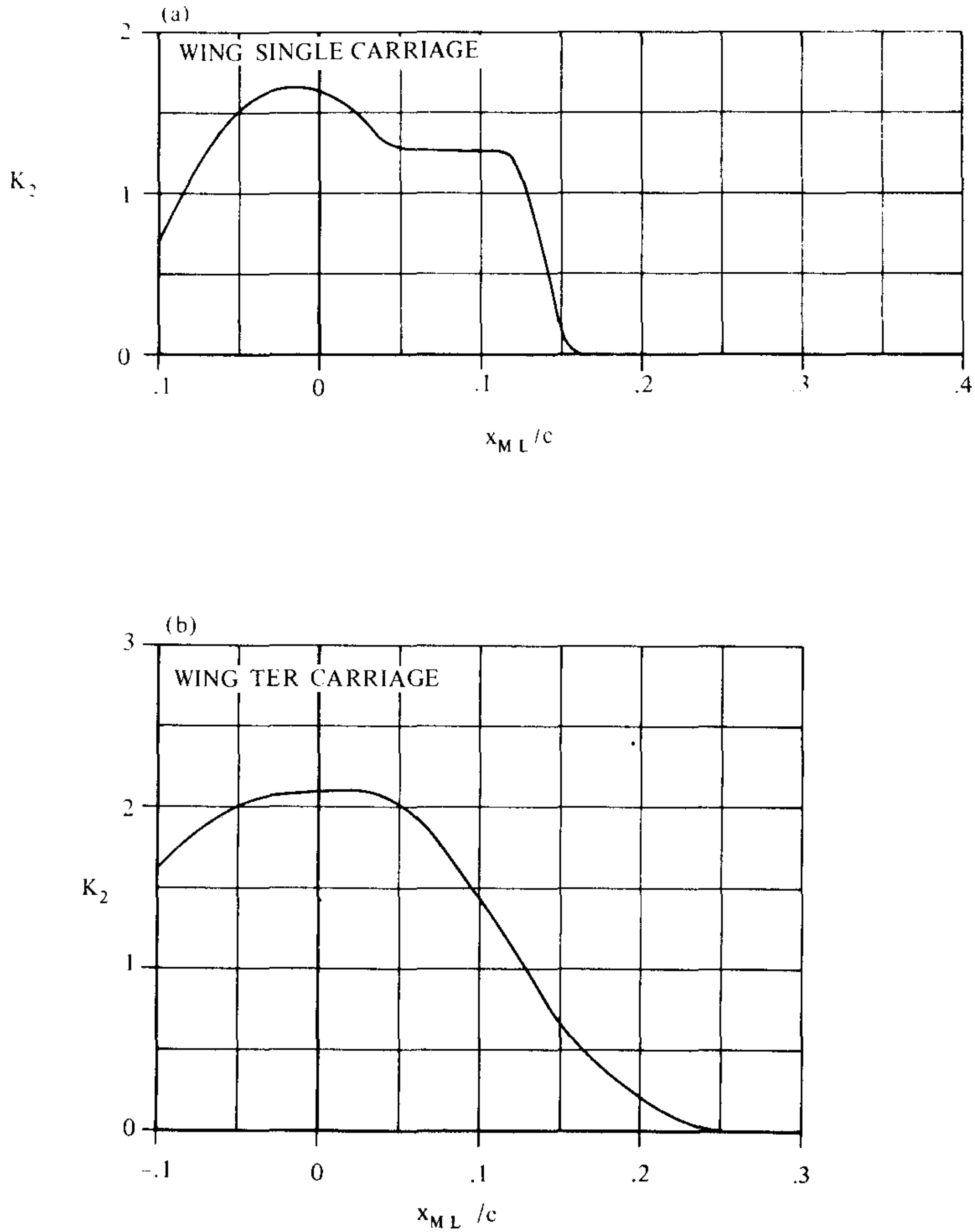
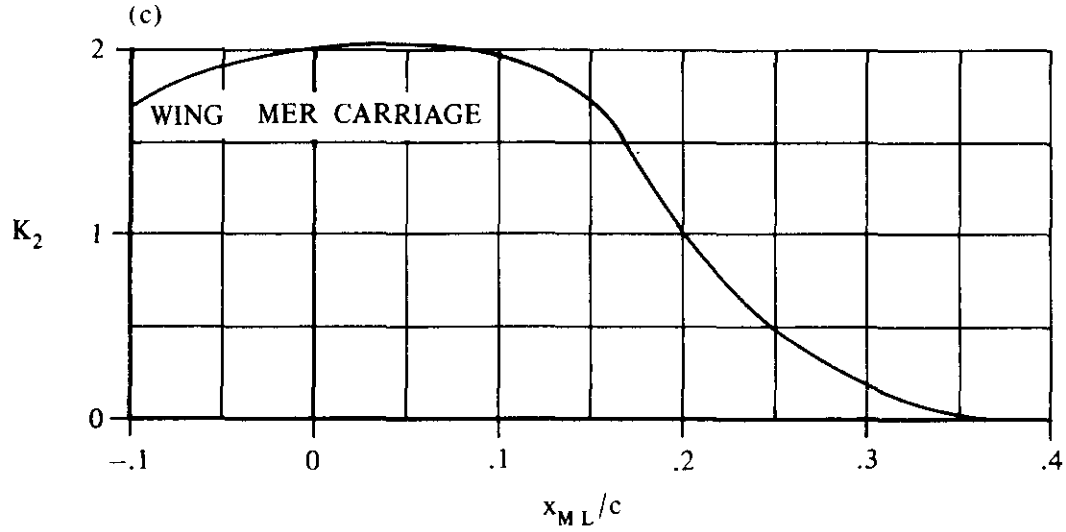


FIGURE 3.3.2-9 NEUTRAL-POINT LONGITUDINAL CORRECTION FACTOR



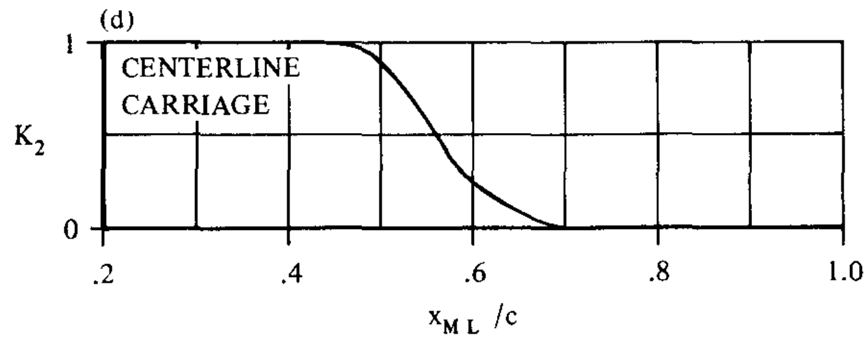


FIGURE 3.3.2-9 (CONTD)

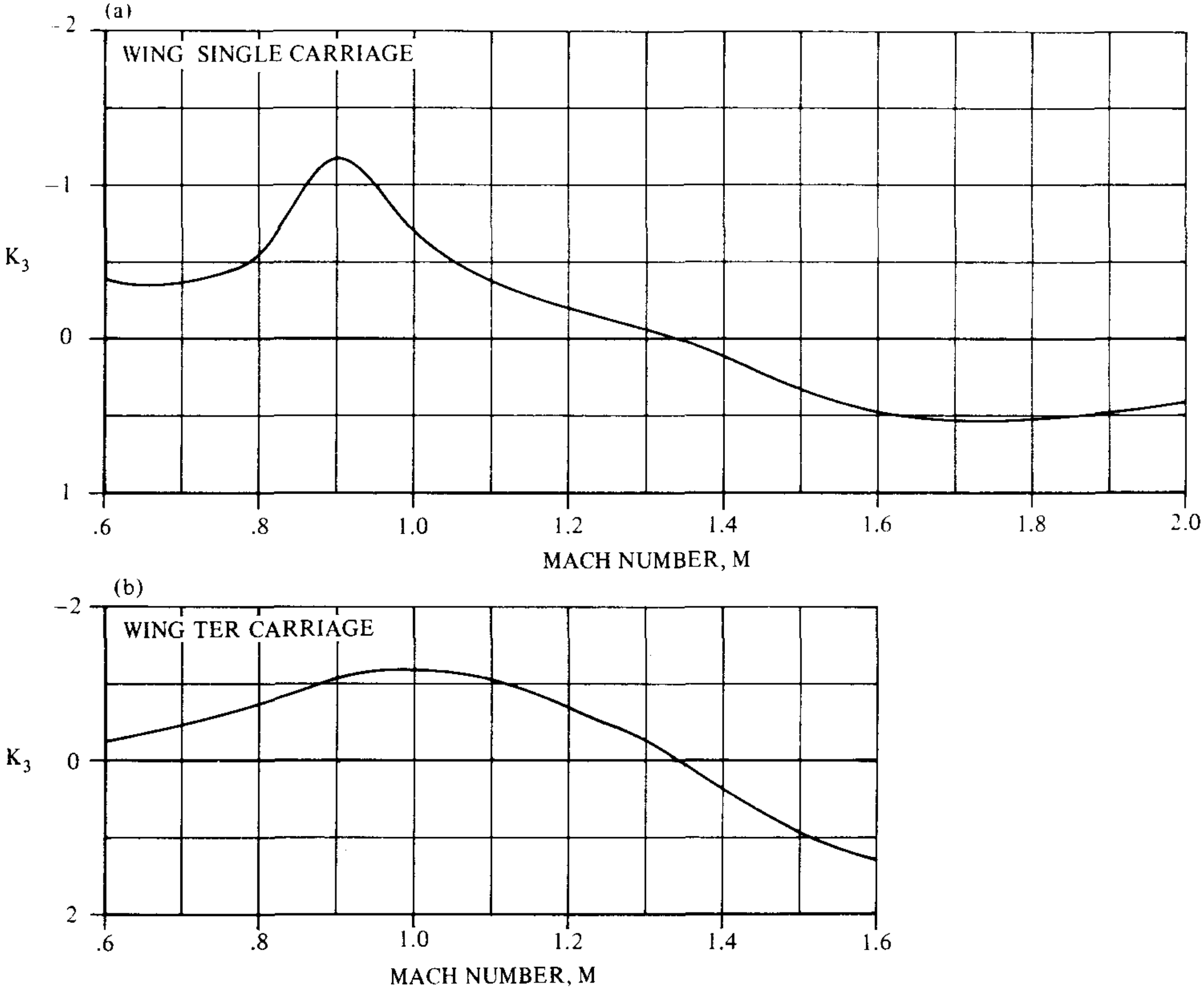
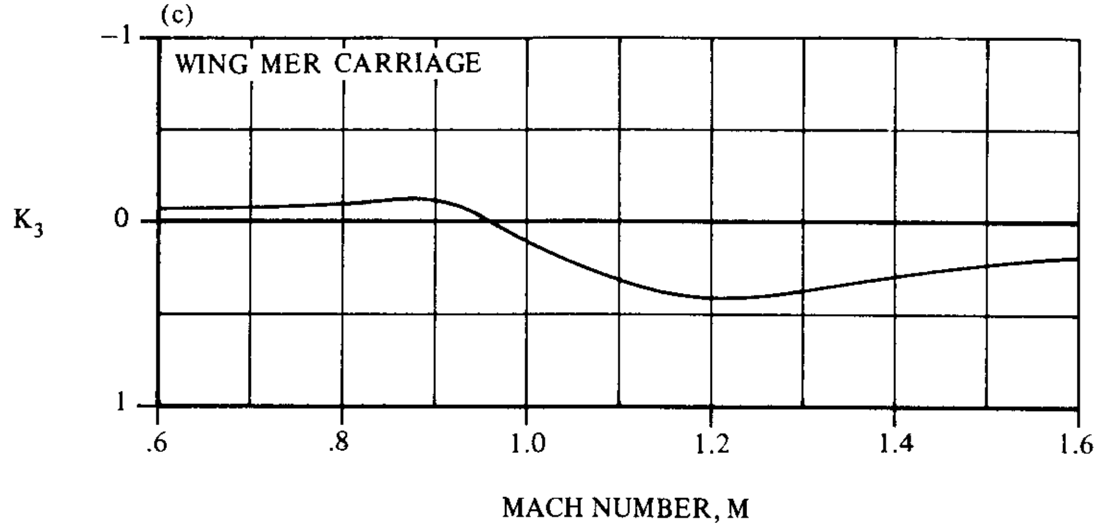


FIGURE 3.3.2-11 NEUTRAL-POINT MACH-NUMBER-CORRECTION FACTOR



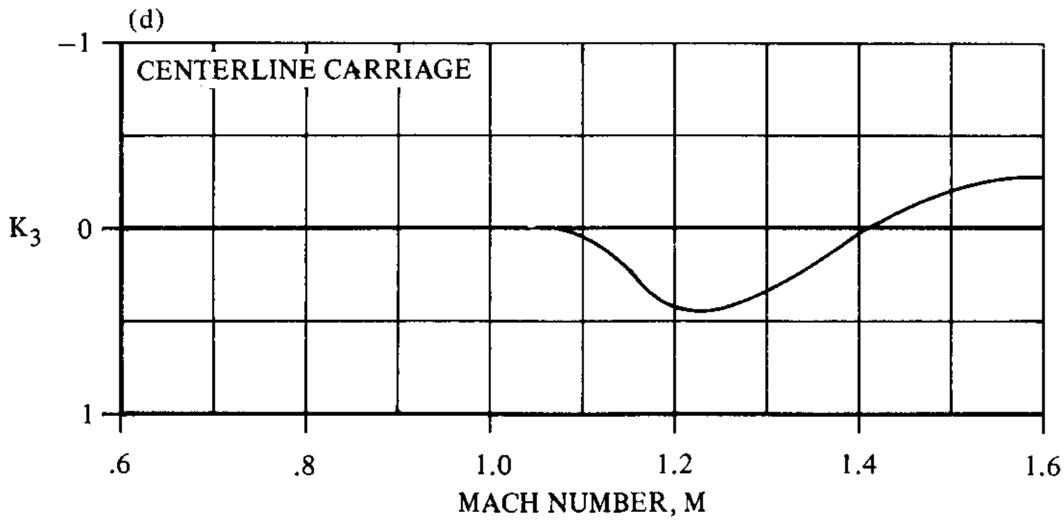


FIGURE 3.3.2-11 (CONTD)

3.3.3 NEUTRAL-POINT SHIFT DUE TO CHANGE IN TAIL EFFECTIVENESS

A method is presented in this section for estimating the neutral-point shift due to the change in horizontal-tail effectiveness caused by wing-mounted external-store installations. The method predicts a neutral-point shift due to all installations (armament stations) on the aircraft

The Datcom Method is taken from Reference 1 and is empirical in nature. The method is applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The limitations on configuration and Mach-number range are summarized in Table 3.3-A. The user is cautioned that the neutral-point shift predicted by this method should be considered as only a first approximation because of the limited data base used in deriving the method. Since the method was developed from F-4 and A-7 aircraft wind-tunnel data, special care should be taken when applying the method to aircraft with horizontal-tail spans and vertical locations substantially different from these aircraft. Additional limitations pertaining to the method are listed below.

1. The method has been verified for the Mach-number range indicated in the figures associated with the method. Caution should be used in extrapolating the empirical curves beyond the given Mach-number range.

2. The method has not been verified for configurations in which flaps, slats, or other flow-disrupting devices are deployed.

3. The method is applicable for sideslip angles less than 4°.

The effect due to a pair of symmetrical installations can be computed by doubling the effect of one side.

A. SUBSONIC

DATCOM METHOD

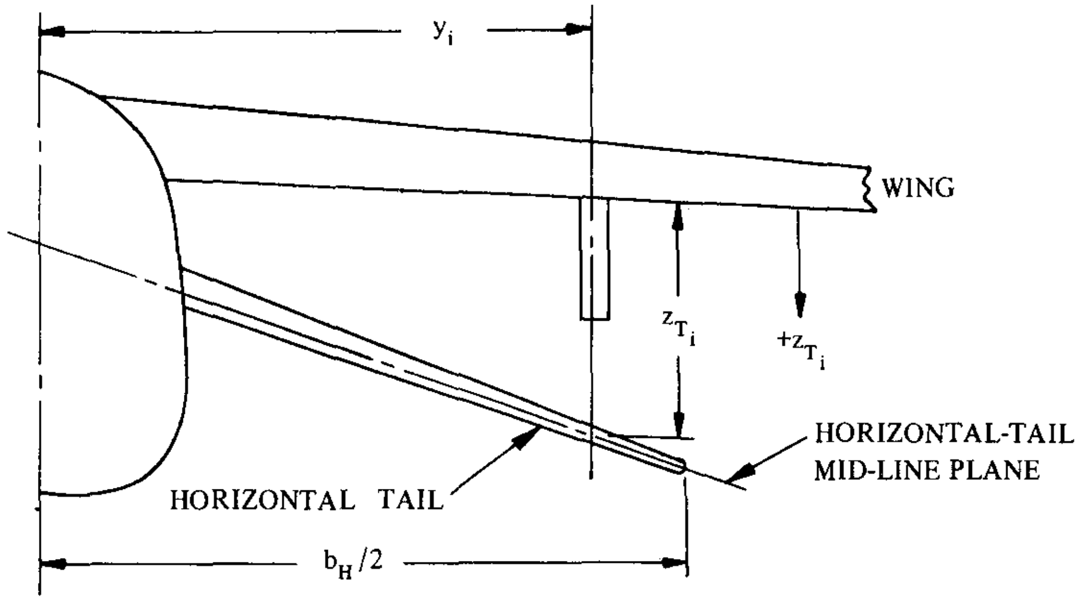
The neutral-point shift in inches, positive for aft shift, due to the change in tail effectiveness from store installations is given by

$$\Delta x_{n.p._3} = \sum_{i=1}^{N_I} \left(\Delta x'_{n.p._3}\right)_i K_{y_i} K_{z_i} \qquad 3.3.3\text{-a}$$

where

N_I is the total number of store installations on the aircraft.

$\Delta x'_{n.p._3}$ is the neutral-point horizontal-tail term obtained from Figures 3.3.3-5a and -5b as a function of configuration and Mach number. For fuselage mounted store installations $\Delta x'_{n.p._3} = 0$.



SKETCH (a)

K_{y_i} is the horizontal-tail span-location factor obtained from Figure 3.3.3-6a as a function of $\frac{y_i}{b_H/2}$ where

- y_i is the spanwise distance from the fuselage centerline to the location of installation i (illustrated in Sketch (a)).

- b_H is the horizontal-tail span (illustrated in Sketch (a)).

K_{z_i} is the horizontal-tail vertical-location factor obtained from Figure 3.3.3-6b as a function of $\frac{z_{T_i}}{b_H/2}$ where

- z_{T_i} is the vertical distance from the wing lower surface at installation i to the horizontal-tail mid-line plane (illustrated in Sketch (a)).

Sample Problem

Given: A swept-wing subsonic-fighter aircraft from Reference 2 described in the Sample Problem of Paragraph A of Section 3.3.1. (See Pages 3.3.1-9 and 3.3.1-10 for identification of store installations.)

Additional Data:

$y_1 = y_5 = 113.75$ in.. $\quad y_2 = y_4 = 78.8$ in. $\quad b_H/2 = 68$ in. $\quad M = 0.6$

$z_{T_1} = z_{T_5} = -59.8$ in. $\quad z_{T_2} = z_{T_4} = -59.8$ in.

Compute:

Expand Equation 3.3.3-a to identify the terms that need to be computed, recalling that the wing installations are symmetrically loaded. Installation 3 is a fuselage mounted installation and the contribution of that installation is zero.

$$\Delta x_{n.p._3} = 2\left(\Delta x'_{n.p._3}\right)_1 K_{y_1} K_{z_1} + 2\left(\Delta x'_{n.p._3}\right)_2 K_{y_2} K_{z_2}$$

$\left(\Delta x'_{n.p._3}\right)_1 = 0.48$ (Figure 3.3.3-5a, single carriage)

$\left(\Delta x'_{n.p._3}\right)_2 = 0.80$ (Figure 3.3.3-5b, multiple carriage)

$$\frac{y_1}{b_H/2} = \frac{113.75}{68} = 1.67$$

$$\frac{z_{T_1}}{b_H/2} = \frac{-59.8}{68} = -0.88$$

$$\frac{y_2}{b_H/2} = \frac{78.8}{68} = 1.16$$

$$\frac{z_{T_2}}{b_H/2} = \frac{-59.8}{68} = -0.88$$

$K_{y_2} = 0.57$ (Figure 3.3.3-6a)

Referring to Figure 3.3.3-6a it is seen that $y_i/(b_H/2)$ is beyond the range of the design chart. This suggests that if the store installation is far enough outboard of the tip of the horizontal tail, the increment in neutral-point shift due to that particular installation is negligible. Therefore, for this configuration it is assumed that $K_{y_1} = 0$.

Referring to Figure 3.3.3-6b it is seen that $z_{T_i}/(b_H/2)$ for both Installations 1 and 2 are well beyond the range of the design chart. It seems reasonable to assume that the value of K_{z_i} will asymptotically approach zero as the vertical distance between the store installation and the horizontal tail is increased. Therefore, for this configuration it is assumed that $K_{z_1} = K_{z_2} = 0$.

Solution:

$$\Delta x_{n.p._3} = \sum_{i=1}^{N_I} \left(\Delta x'_{n.p._3}\right)_i K_{y_i} K_{z_i}$$ (Equation 3.3.3-a)

$$= 2\left(\Delta x'_{n.p._3}\right)_1 \; K_{y_1} K_{z_1} \; + \; 2\left(\Delta x'_{n.p._3}\right)_2 \; K_{y_2} K_{z_2}$$

$$= 2(0.48)(0)(0) \; + \; 2(0.80)(0.57)(0)$$

$$= 0$$

The calculated value of $\Delta x_{n.p._3}$ is summed with $\Delta x_{n.p._1}$ and $\Delta x_{n.p._2}$ (computed in Sections 3.3.1 and 3.3.2 respectively) in the Sample Problem of Section 3.3.4 to obtain the total shift in neutral point.

B. TRANSONIC

The method presented in Paragraph A of this section is also valid in the transonic speed range.

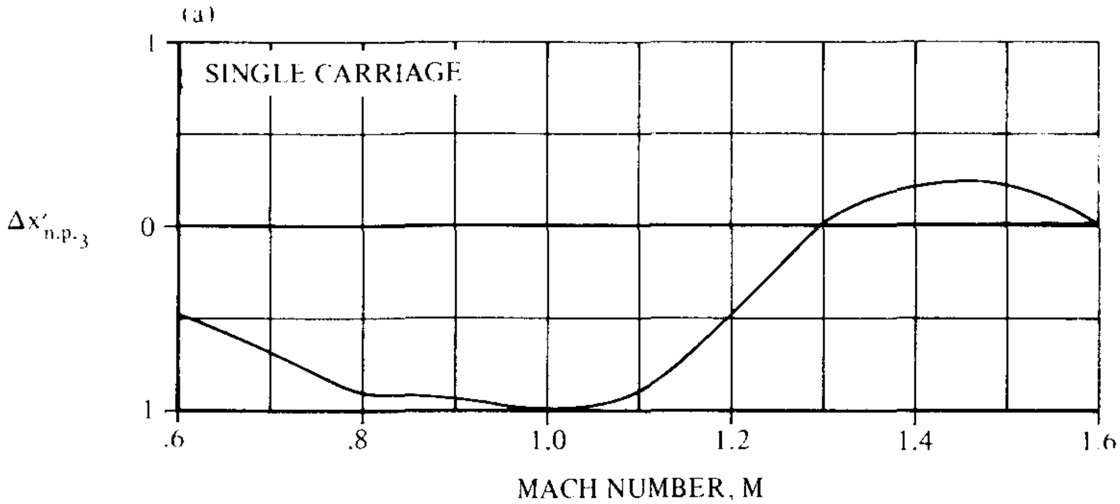
C. SUPERSONIC

The method presented in Paragraph A of this section is also valid in the supersonic speed range up to a Mach number of 1.6 to 2.0 as indicated in Table 3.3-A. The maximum Mach number provided in the figures should indicate the level to which the method is substantiated. Caution should be used when extrapolating the data beyond the Mach-number range provided in the figures.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer. McDonnell Douglas Corporation Rept. DAC-67425, 1968. (U)



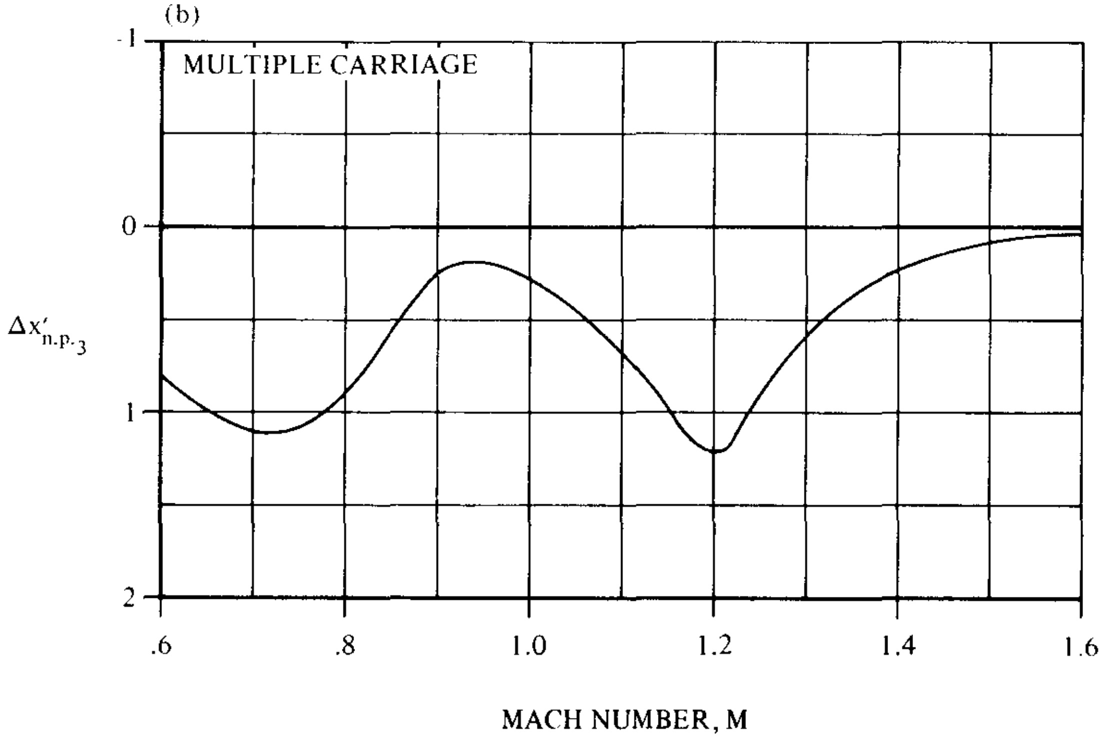


FIGURE 3.3.3-5 NEUTRAL-POINT HORIZONTAL-TAIL TERM

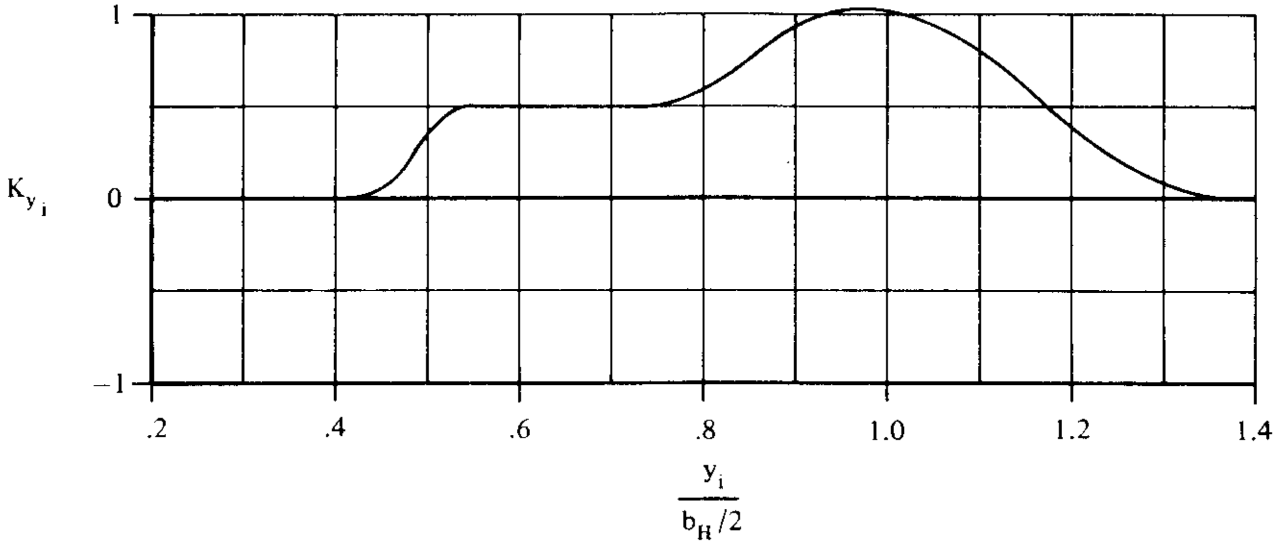


FIGURE 3.3.3-6 a HORIZONTAL-TAIL SPAN-LOCATION FACTOR

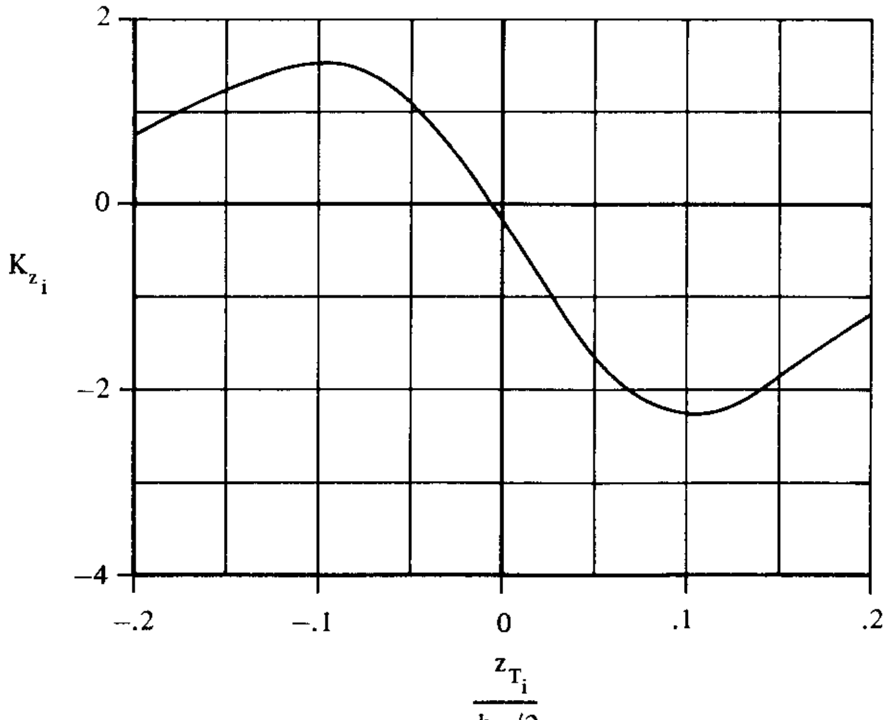


FIGURE 3.3.3-6 b HORIZONTAL-TAIL VERTICAL-LOCATION FACTOR

3.3.4 TOTAL NEUTRAL-POINT SHIFT DUE TO EXTERNAL STORES

A method is presented in this section for estimating the total shift in aircraft neutral point due to external-store installations. The method predicts the neutral-point shift for symmetric, asymmetric, and multiple-installation loading configurations

The Datcom Method is taken from Reference 1 and is empirical in nature. The method is applicable to aircraft of conventional design and essentially symmetrical store shapes with no major shape protuberances. The limitations on configuration and Mach-number range are summarized in Table 3.3-A. Additional limitations and assumptions pertaining to the method are listed below

1. The method is not applicable to wing-tip or wing-tangent-mounted stores.

2. Fuselage-mounted installations must be located on the fuselage centerline.

3. The method is not applicable to empty multiple racks.

4. The effect of empty pylons on neutral point is considered to be negligible.

5. The method has been verified for the Mach-number range given in Table 3.3-A. Caution should be used in extrapolating the empirical curves beyond the given Mach-number range.

6. The method has not been verified for configurations in which flaps, slats, or other flow-disrupting devices are deployed.

7. The method gives the best results for an angle-of-attack range from 0 to 8°, although the method can be used for higher angles of attack.

8. The data base used in deriving the method relied heavily on swept-wing tactical-combat-aircraft wind-tunnel data.

9. The method is applicable for sideslip angles less than 4°.

The procedure for computing the total neutral-point shift requires calculation of increments due to lift transfer from stores to aircraft, interference effects on the wing flow field, and change in tail effectiveness. These increments are computed by the methods of Sections 3.3.1, 3.3.2, and 3.3.3, respectively. The increments are computed for the entire loading configuration and then summed by the method of this section to obtain the total increment.

A. SUBSONIC

DATCOM METHOD

The total neutral-point shift in inches, positive for aft shift, due to external-store installations is given by

$$\Delta x_{n.p.} = \Delta x_{n.p._1} + \Delta x_{n.p._2} + \Delta x_{n.p._3} \qquad 3.3.4\text{-a}$$

where

$\Delta x_{n.p._1}$ is the shift in neutral point due to lift transfer from the stores to the clean aircraft (in.), obtained from Section 3.3.1.

$\Delta x_{n.p._2}$ is the shift in neutral point due to the interference effects on the wing flow field (in.), obtained from Section 3.3.2.

$\Delta x_{n.p._3}$ is the shift in neutral point due to the change in tail effectiveness caused by external stores (in.), obtained from Section 3.3.3.

Reference 1 states that the prediction accuracies are such that the predicted values of neutral-point shift are nominally within about 1 inch of the test values 60 percent of the time, and within 4 inches 92 percent of the time.

Sample Problem

Given: A swept-wing subsonic-fighter aircraft from Reference 2 loaded with external-store installations described in the Sample Problem of Paragraph A of Section 3.3.1.

Compute:

$\Delta x_{n.p._1} = -0.114$ in. (Sample Problem, Paragraph A, Section 3.3.1)

$\Delta x_{n.p._2} = 0.077$ in. (Sample Problem, Paragraph A, Section 3.3.2)

$\Delta x_{n.p._3} = 0$ (Sample Problem, Paragraph A, Section 3.3.3)

$$\Delta x_{n.p.} = \Delta x_{n.p._1} + \Delta x_{n.p._2} + \Delta x_{n.p._3} \qquad \text{(Equation 3.3.4-a)}$$

$$= -0.114 + 0.077 + 0 = -0.037 \text{ in.}$$

B. TRANSONIC

The method presented in Paragraph A of this section is also valid in the transonic speed range. The expected accuracy of the method is less than that in the subsonic speed range.

C. SUPERSONIC

The method presented in Paragraph A of this section is also valid in the supersonic speed range. The expected accuracy of the method is less than that in the subsonic speed range.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer. McDonnell Douglas Corporation Rept. DAC-67425, 1968. (U)

3.4 EFFECTS OF EXTERNAL STORES ON AIRCRAFT SIDE FORCE

A method is presented in this section for estimating the increment in aircraft side force due to external-store installations. The method predicts an incremental change in the side-force-due-to-sideslip derivative, ΔC_{Y_β}, which can be added to the clean aircraft C_{Y_β} to obtain the aircraft-with-stores C_{Y_β}.

The Datcom Method is taken from Reference 1 and is empirical in nature. The method is limited to the store-loading configurations and Mach-number range presented in Table 3.4-A

TABLE 3.4-A

LOADING AND MACH-NUMBER LIMITATIONS

Mounting Location	Carriage Mode	Mount/Loading Type	Mach-Number Range
Wing	Single	Pylon – Empty	0.6 → 2.0
		Pylon – Store	
	Multiple	Pylon – Empty MER	0.6 → 1.6
		Pylon – Fully Loaded MER	
		Pylon – Empty TER	
		Pylon – Fully Loaded TER	
Fuselage	Single	Tangent	0.6 → 2.0
		Pylon – Empty	
		Pylon – Store	
	Multiple	Tangent – Empty MER	0.6 → 1.6
		Tangent – Fully Loaded MER	
		Tangent – Empty TER	
		Tangent – Fully Loaded TER	
		Pylon – Empty MER	
		Pylon – Fully Loaded MER	
		Pylon – Empty TER	
		Pylon – Fully Loaded TER	

The Datcom Method is applicable to mixed-loading configurations obtained by combining two or more loadings specified in Table 3.4-A. The method was developed from symmetrically-loaded-stores data and is therefore limited primarily to symmetrically-loaded configurations. However, certain asymmetric configurations may be treated by the method. It should be noted that one-half of the incremental side force due to a symmetrical-store loading is not necessarily equivalent to the side force produced by half of that loading carried asymmetrically. Where there are aircraft components near the stores, or if strong lateral flow fields exist due to angle of attack, part of the aerodynamic side force induced by an installation on one side of the aircraft is cancelled by an opposite force on the other side. The Datcom Method is considered applicable to asymmetric configurations for which the sidewash change due to angle of attack is zero and fuselage effects are negligible.

The prediction method was developed from data based on an angle of attack of 5°. No method is provided to account for the effect of angle-of-attack change on side force, but the method is considered to be valid throughout the normal cruise angle-of-attack range.

The method is subject to the following additional limitations and assumptions:

1. The method has been verified for the Mach-number ranges given in Table 3.4-A. Caution should be used in extrapolating the empirical curves beyond the given Mach-number ranges.

2. The method has not been verified for configurations in which flaps, slats, or other flow-disrupting devices are deployed.

3. The store shape is essentially symmetrical with no major shape protuberances.

4. The data base used in deriving the method relied heavily on swept-wing tactical-combat-aircraft wind-tunnel data.

5. No tail effects are included.

6. The method is applicable for sideslip angles less than 8°.

The side-force-derivative increment is composed of a basic contribution due to the store installations and a contribution due to interference between adjacent installations (when separation distance is sufficiently small).

A. SUBSONIC

DATCOM METHOD

The increment in C_{Y_β}, based on wing reference area, due to external-store installations is given by

$$\Delta C_{Y_\beta} = \frac{1}{S_W}\left[\sum_{i=1}^{N_I} \frac{1}{2}\left(Y_{B_\beta}\right)_i + \sum_{j=1}^{N_P}\left(Y_{A_\beta}\right)_j\right] \qquad 3.4\text{-a}$$

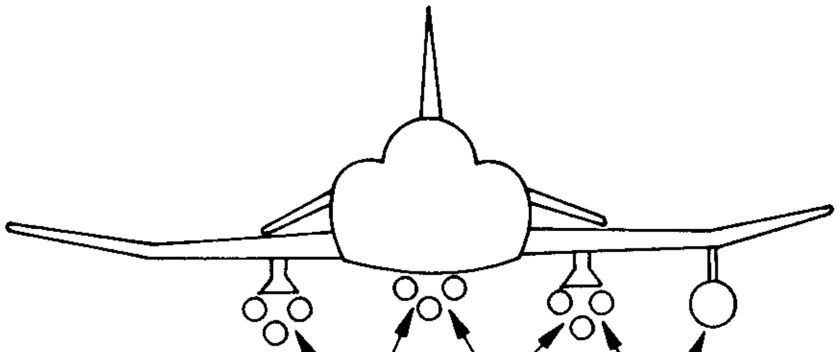
where

S_W is the wing reference area (ft^2).

N_I is the total number of store installations.

N_P is the total number of pairs of adjacent-store installations carried. (See Sketch (a).)

Y_{B_β} is the basic side-force contribution (ft^2/deg) per degree sideslip due to a symmetrical pair of external-store installations, calculated in Step 1 below. Since the empirical equations and figures for Y_{B_β} are based on a pair of symmetrical-store installations, Y_{B_β} must be divided by 2 before summing over the total number of installations, thus allowing for the inclusion of asymmetrical loading cases.



SKETCH (a)

Y_{A_β} is the side-force contribution (ft^2/deg) per degree sideslip due to interference effects from a pair of adjacent external-store installations, calculated in Step 2 below.

ΔC_{Y_β} is computed by using the following steps:

1. Compute Y_{B_β} for each installation.
2. Compute Y_{A_β} for each pair of adjacent installations.
3. Compute ΔC_{Y_β}.

Step 1. Compute Y_{B_β} for each installation:

The various loading configurations are assigned reference numbers in Table 3.4-B.

TABLE 3.4-B

CONFIGURATION SUMMARY

Mounting \ Carriage	Empty	Single	Empty MER	Full MER	Empty TER	Full TER
Wing-Pylon	1	2	3	4	5	6
Fuselage-Tangent	–	7	8	9	10	11
Fuselage-Pylon	12	13	14	15	16	17

$$Y_{B_\beta} = -(B_P + B_R + B_N + B_X + B_Y)\, K_M \qquad 3.4\text{-b}$$

where

B_P is the pylon contribution given by

$$B_P = \frac{K_{PC}\, h_p^{\,2}}{144} \qquad 3.4\text{-c}$$

where

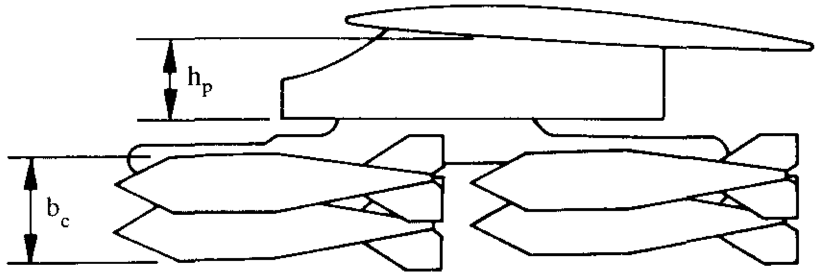
K_{PC} is a pylon constant obtained from Table 3.4-C.

TABLE 3.4-C

PYLON CONSTANT

Configuration	1	2	3	4	5	6	7-11	12	13	14	15	16	17
K_{PC}	.10	.15	.14	.14	.12	.12	0	.10	.15	.14	.14	.12	.12

h_p is the average pylon height (in.). (See Sketch (b).)



SKETCH (b)

B_R is the rack contribution.

For Configurations 2, 7, and 13 the store contribution is included and

$$B_R = K_F \frac{{b_F}^2}{144} + \frac{(0.09)\, d_S^2}{144} \qquad 3.4\text{-d}$$

where

K_F is a fin constant given by

$K_F = 0.082$ for + and X fins

$K_F = 0.107$ for V fins

b_F is the store-fin span (in.). (Total span measured tip-to-tip. For V fins, the total span of the actual fin and its mirror image.)

d_S is the store maximum diameter (in.).

For other configurations, B_R is given by Table 3.4-D.

TABLE 3.4-D

RACK CONTRIBUTION

Configuration	1	3	4	5	6	8	9	10	11	12	14	15	16	17
B_R	0	.325	.325	.183	.183	.325	.325	.183	.183	0	.325	.325	.183	.183

B_N is the store contribution

For Configurations 1, 3, 5, 8, 10, 12 ,14, and 16 $B_N = 0$.

For single-store installations (Configurations 2, 7, and 13), B_N is included in the B_R computation.

For Configurations 4, 6, 9, 11, 15, 17

$$B_N = 0.0666 \left(\frac{b_c}{12}\right)^2 \left(\frac{b_F}{d_S}\right)^2 (R_D + 1) \qquad 3.4\text{-e}$$

where

b_c is the maximum vertical span (in.) of the side projection of the store cluster in a vertical plane, excluding protruding fins. (See Sketch (b).)

R_D is a correlation factor given by Figure 3.4-12 for Configurations 4, 9, and 15. $R_D = 0$ for Configurations 6, 11, and 17. All other terms in Equation 3.4-e have been previously defined.

B_X is the contribution due to pylon longitudinal location.

For fuselage-mounted configurations (Configurations 7-17) $B_X = 0$.

For wing-pylon-mounted configurations (Configurations 1-6), B_X is given by

$$B_X = (B_P + B_R + B_N)(K_{XP} - 1) \qquad 3.4\text{-f}$$

where B_P, B_R, B_N were previously defined and

$$K_{XP} = (1 + A_2)(A_1) \left(\begin{array}{c} K_{XP} \text{ has a maximum} \\ \text{value of } 1.0 \end{array}\right) \qquad 3.4\text{-g}$$

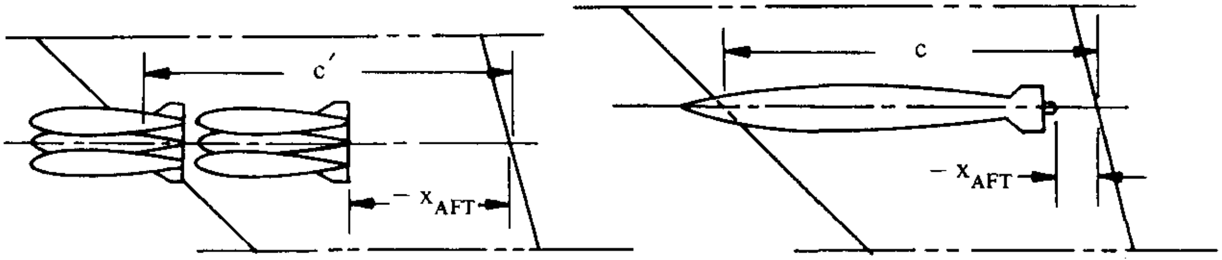
where

A_2 is a store-size correlation factor obtained from Figure 3.4-13 as a function of the maximum store diameter, d_S. For Configurations 1, 3, and 5, the value of A_2 is zero.

A_1 is a longitudinal-location correlation factor obtained from Figure 3.4-14 as a function of x_{AFT}/c where

x_{AFT} is the longitudinal distance (in.) from the local wing trailing edge to the trailing edge of pylon, rack, or store as appropriate (i.e., the most aft component), positive in the aft direction. (See Sketch (c).)

c is the local wing chord at the store installation (in.). (See Sketch (c).)



MULTIPLE STORES SINGLE STORE

SKETCH (c)

B_Y is the contribution due to spanwise location of the pylon installation.

For fuselage-mounted configurations (Configurations 7-17),

$$B_Y = 0 \qquad 3.4\text{-h}$$

For wing-pylon-mounted configurations (Configurations 1-6) on low-wing aircraft,

$$B_Y = K_y \left(\frac{y_i}{b_W/2} - 0.350\right) \qquad 3.4\text{-i}$$

For wing-pylon-mounted configurations on high-wing aircraft,

$$B_Y = K_y \left(\frac{y_i'}{b_e/2} - 0.350\right) \qquad 3.4\text{-j}$$

where

K_y is a store-installation-depth factor obtained from Figure 3.4-15 as a function of z, the maximum depth (in.) of the store installation.

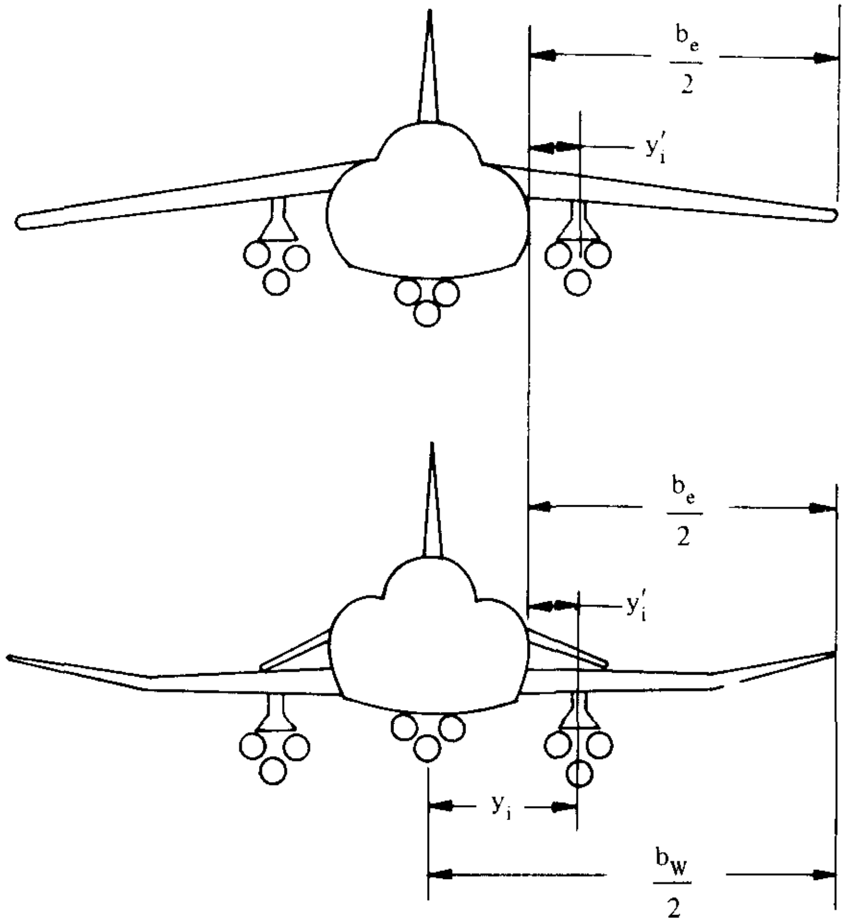
y_i is the spanwise distance from the fuselage centerline to the location of installation i (illustrated in Sketch (d)).

b_W is the wing span.

y_i' is the spanwise distance from the outboard edge of the fuselage to the location of installation i (illustrated in Sketch (d)).

b_e is the exposed wing span (illustrated in Sketch (d)).

K_M is a side-force Mach-effect factor obtained from Figure 3.4-16 as a function of Mach number and $\frac{y_i'}{b/2}$ where $b = b_W$ for low-wing aircraft, $b = b_e$ for high-wing aircraft, and y_i', b_W, and b_e were previously defined.



SKETCH (d)

Step 2. Compute Y_{A_β} for each pair of adjacent installations.

Determine the number of pairs of adjacent installations (see Sketch (a)).

Compute Y_{A_β} for each adjacent pair:

$$Y_{A_\beta} = -\left[\left(Y_{B_\beta}\right)_1 + \left(Y_{B_\beta}\right)_2\right] R_{NEG} \tag{3.4-k}$$

where

$\left(Y_{B_\beta}\right)_1$ is obtained from Equation 3.4-b for the first of the pair of installations.

$\left(Y_{B_\beta}\right)_2$ is obtained from Equation 3.4-b for the second of the pair of installations.

R_{NEG} is an adjacent-store interference factor obtained from Figure 3.4-17 as a function of $(X_F + X_A)/(\ell_1 + \ell_2)$ and Mach number where

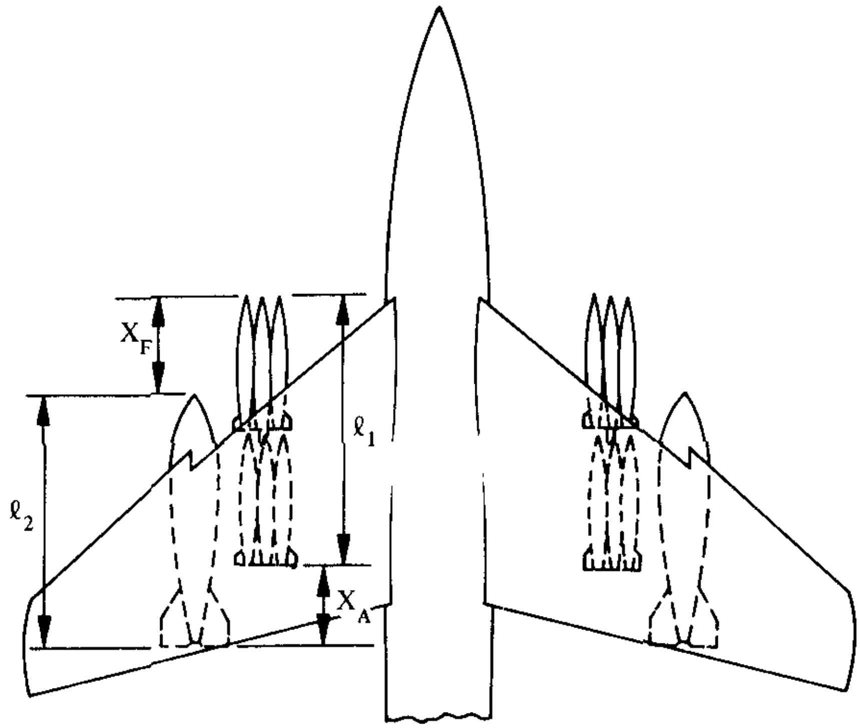
X_F is the absolute longitudinal distance from the nose of one store installation to the nose of the adjacent installation. (See Sketch (e).)

X_A is the absolute longitudinal distance from the trailing edge of one store installation to the trailing edge of the adjacent installation. (See Sketch (e).)

ℓ_1 and ℓ_2 are the lengths of the two store installations. (See Sketch e).)

For no adjacent store installations,

$$Y_{A_\beta} = 0 \tag{3.4-ℓ}$$



SKETCH (e)

Step 3. Compute ΔC_{Y_β}

ΔC_{Y_β} is computed from Equation 3.4-a by summing the Y_{B_β} values obtained in Step 1 for each installation and the Y_{A_β} values obtained from Step 2 for each pair of adjacent installations.

Reference 1 states that the method nominally results in prediction errors of 10 to 15 percent. A comparison of test data with results calculated by this method is provided in Table 3.4E. Additional comparisons of test and calculated results are found in Reference 1.

Sample Problem

Given: A swept-wing subsonic-fighter aircraft from Reference 2 with one 300-gal tank, pylon mounted on each wing.

Aircraft Data:

$S_W = 260 \text{ ft}^2$ Low-wing configuration

Store Data:

$d_S = 26.5$ in. $b_F = 35.06$ in. + type fins

Installation Data:

$h_p = 11.2$ in. $\frac{y_1}{b_W/2} = 0.320$ $\frac{x_{AFT}}{c} = -0.288$ $z = 37.3$ in

Additional Data:

$M = 0.6$

Compute:

Step 1. Compute Y_{B_β} for each installation. (Since the installations are symmetrical, only one side need be computed). This is Configuration 2 (Table 3.4-B)

$K_{PC} = 0.15$ (Table 3.4-C)

$$B_P = \frac{K_{PC}\, h_p^{\,2}}{144} = \frac{(0.15)(11.2)^2}{144} = 0.1307 \qquad \text{(Equation 3.4-c)}$$

$K_F = 0.082$ (+ type fins)

$$B_R = K_F \frac{b_F^{\,2}}{144} + \frac{(0.09) d_S^{\,2}}{144} \qquad \text{(Equation 3.4-d)}$$

$$= \frac{(0.082)(35.06)^2}{144} + \frac{(0.09)(26.5)^2}{144}$$

$$= 1.1389$$

B_N is included in the B_R computation (Configuration 2)

$A_2 = 0.365$ (Figure 3.4-13)

$A_1 = 0.77$ (Figure 3.4-14, single store)

$K_{XP} = (1 + A_2)(A_1)$ (maximum value of 1.0) (Equation 3.4-g)

$$= (1 + 0.365)(0.77) = 1.05;\ \text{use } K_{XP} = 1.0$$

$$B_X = (B_P + B_R + B_N)(K_{XP} - 1) \qquad \text{(Equation 3.4-f)}$$

$$= (0.1307 + 1.1389 + 0)(1.0 - 1)$$

$$= 0$$

$$K_Y = 1.95 \qquad \text{(Figure 3.4-15)}$$

$$B_Y = K_Y \left(\frac{y_i}{b_W/2} - 0.350\right) \qquad \text{(Equation 3.4-i)}$$

$$= 1.95\,(0.320 - 0.350) = -0.0585$$

$$K_M = 1.0 \qquad \text{(Figure 3.4-16)}$$

$$Y_{B_\beta} = -(B_P + B_R + B_N + B_X + B_Y)K_M \qquad \text{(Equation 3.4-b)}$$

$$= -(0.137 + 1.1389 + 0 - 0 - 0.0585)(1.0)$$

$$= -1.211$$

Step 2. Compute Y_{A_β} for each pair of adjacent installations. In this case there are no adjacent installations, and $Y_{A_\beta} = 0$.

Step 3. Compute ΔC_{Y_β}:

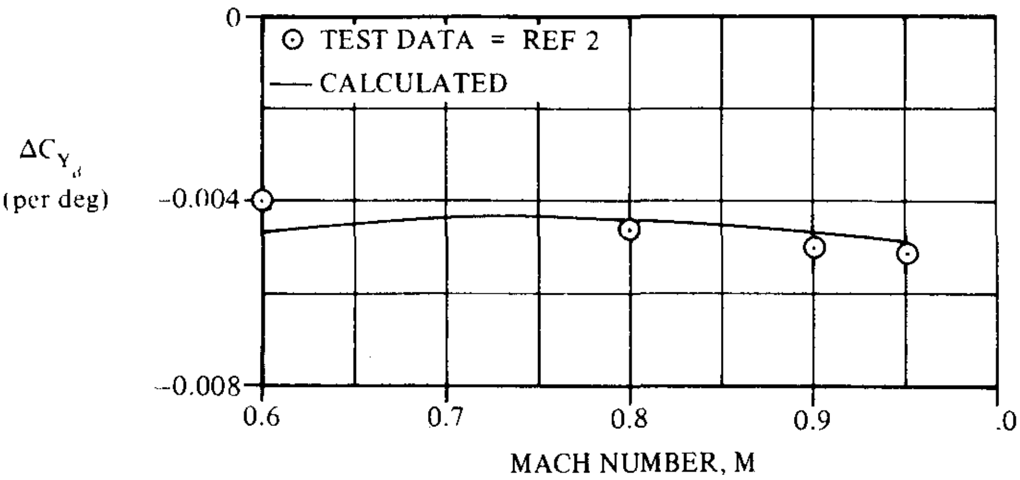
$$\Delta C_{Y_\beta} = \frac{1}{S_W}\left[\sum_{i=1}^{N_I} \frac{1}{2}\left(Y_{B_\beta}\right)_i + \sum_{j=1}^{N_P}\left(Y_{A_\beta}\right)_j\right] \qquad \text{(Equation 3.4-a)}$$

$$= \frac{1}{S_W}\left[\sum_{i=1}^{2} \frac{1}{2}\left(Y_{B_\beta}\right)_i + 0\right]$$

$$= \frac{1}{260}\left[\frac{1}{2}(-1.211) + \frac{1}{2}(-1.211)\right]$$

$$= -0.0047 \text{ per deg}$$

Values of ΔC_{Y_β} at other Mach numbers have been calculated and are shown in comparison to test data from Reference 2 in Sketch (c).



SKETCH (c)

B. TRANSONIC

The method presented in Paragraph A of this section is also valid in the transonic speed range. The user is cautioned that the expected accuracy of the method is less than that expected in the subsonic speed range. A comparison of test data with results calculated by this method at transonic speed is presented in Table 3.4-E.

C. SUPERSONIC

The method presented in Paragraph A of this section is also valid in the supersonic speed range up to a Mach number of 1.6 to 2.0 as indicated in Table 3.4-A. The maximum Mach number provided in the figures should indicate the level to which the method is substantiated by Reference 1. Caution should be used when extrapolating the data beyond the Mach-number range provided in the figures. A comparison of test data with results calculated by this method at supersonic speeds is presented in Table 3.4-E.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer. McDonnell Douglas Corporation Rept. DAC-67425, 1968. (U)

3. Bonine, W. J., et al: Model F/RF-4B-C Aerodynamic Derivatives. McDonnell Douglas Corporation Rept. 9842, 1964 (Rev. 1971). (U)

TABLE 3.4-E

SUBSONIC AND SUPERSONIC EXTERNAL-STORE SIDE FORCE DATA SUMMARY AND SUBSTANTIATION

Ref	Loading Description	α (deg)	M	ΔC_{Y_β} calc (per deg)	ΔC_{Y_β} test (per deg)	ΔC_{Y_β} calc-test (per deg)
2	Wing Station Mounting Left Inboard Pylon-Mounted Single: 300-gal tank Right Inboard Pylon-Mounted Single: 300-gal tank	5	0.6	−0.0047	−0.0040	−0.0007
↓		↓	0.8	−0.0044	−0.0046	0.0002
			0.9	−0.0046	−0.0050	0.0004
			0.95	−0.0048	−0.0051	0.0003
3	Wing Station Mounting Left Inboard Pylon-Mounted Single: Missile Right Inboard Pylon-Mounted Single: Missile	5	0.6	−0.0035	−0.0015	−0.0020
↓		↓	0.9	−0.0039	−0.0020	−0.0019
			1.2	−0.0042	−0.0028	−0.0014
			1.6	−0.0043	−0.0020	−0.0023
			2.0	−0.0022	−0.0020	−0.0002

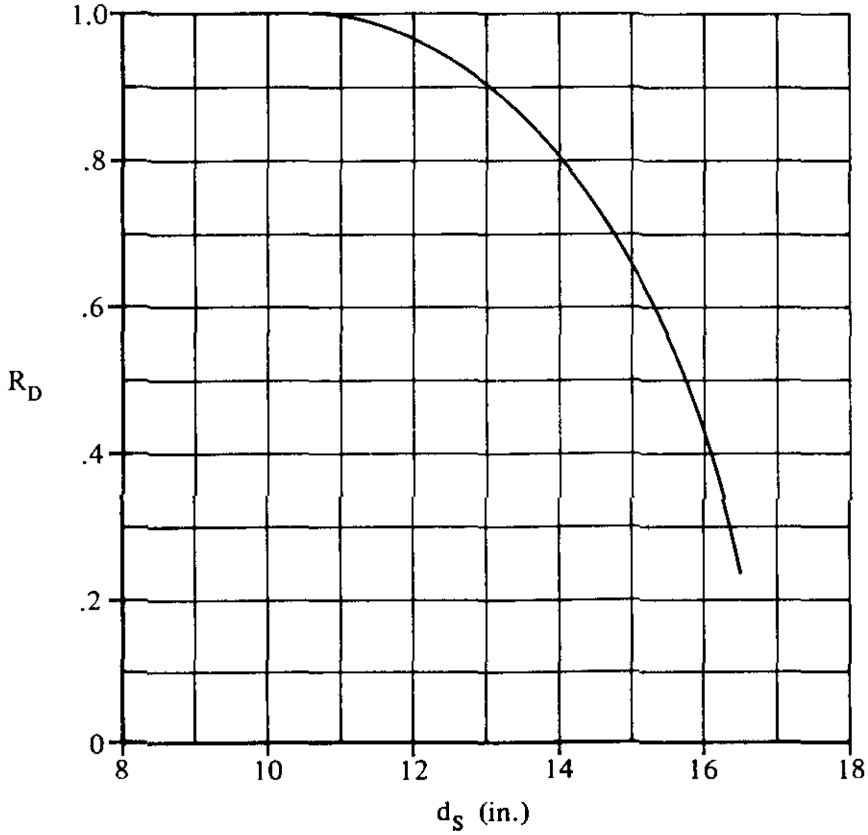


FIGURE 3.4-12 BASIC-STORES-CORRELATION FACTOR

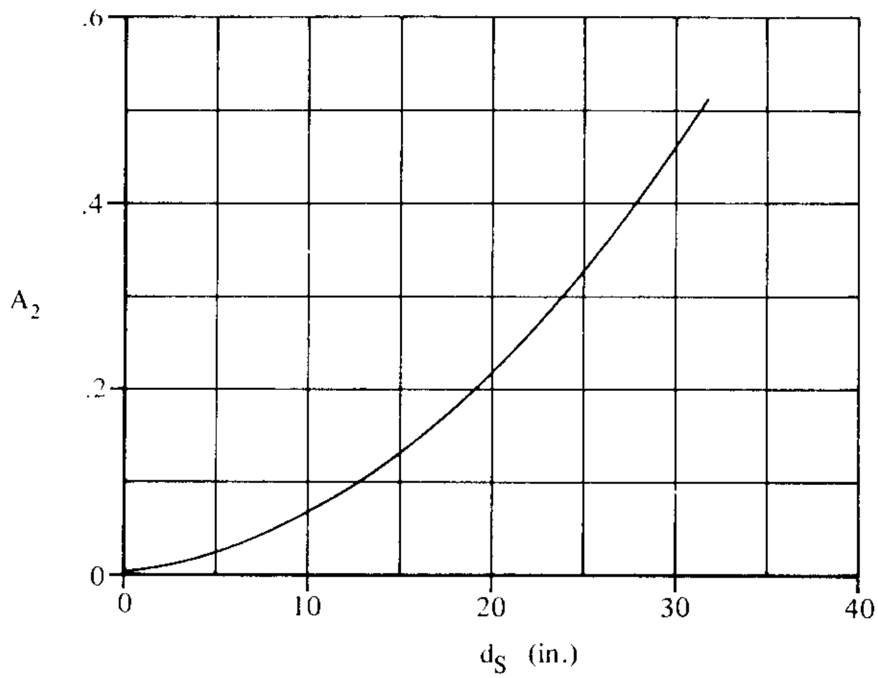


FIGURE 3.4-13 STORE-SIZE CORRELATION FACTOR

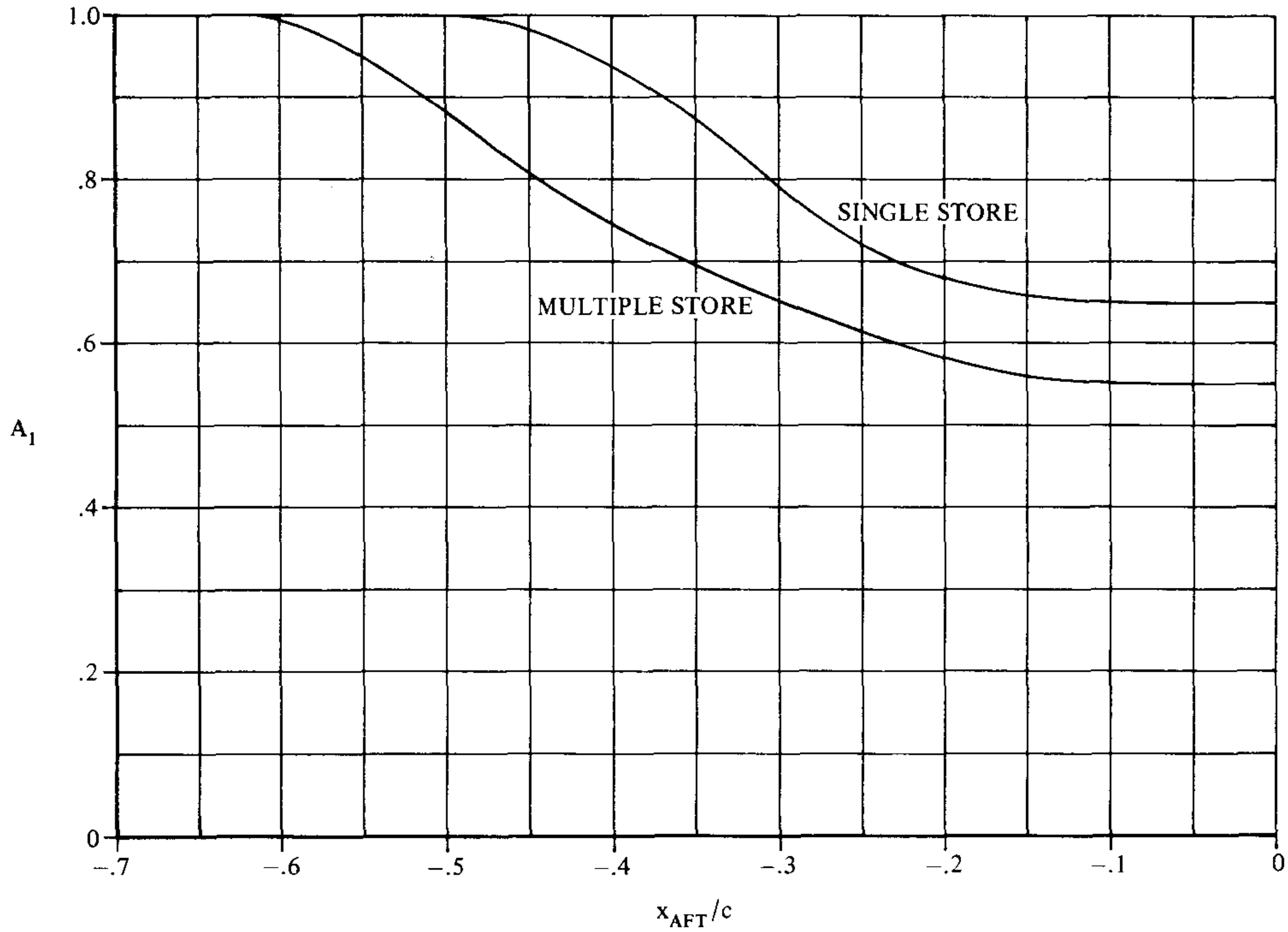


FIGURE 3.4-14 PYLON LONGITUDINAL-LOCATION CORRELATION FACTOR

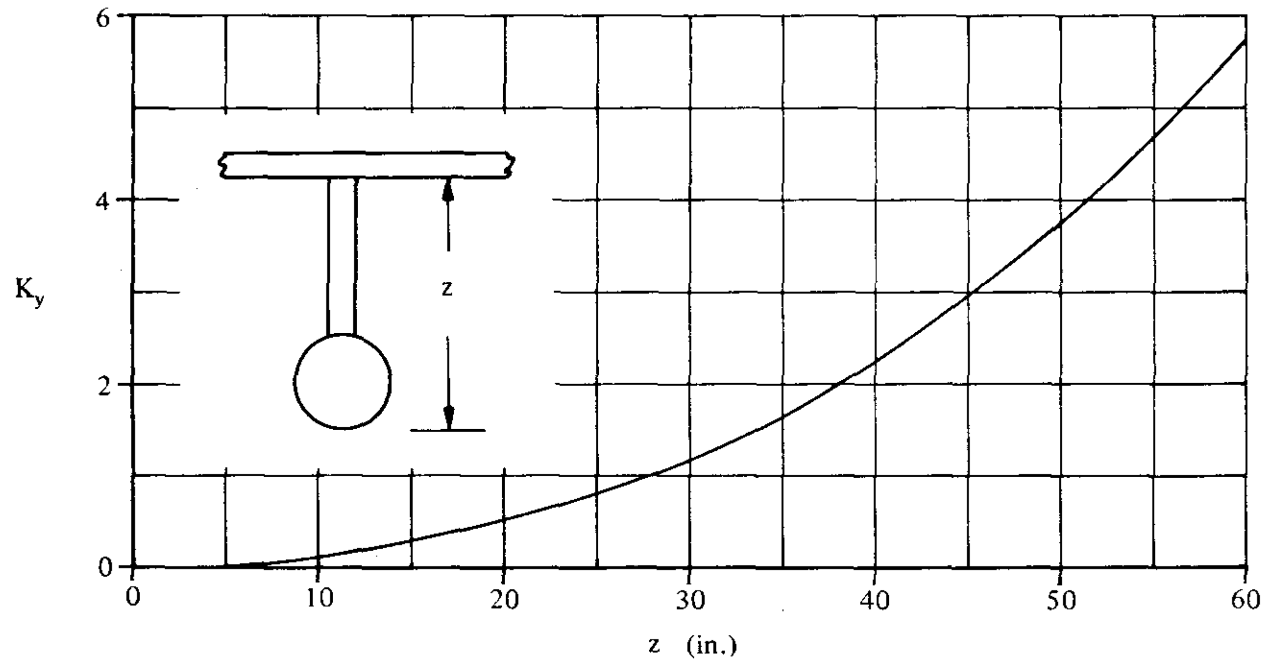


FIGURE 3.4-15 STORE-INSTALLATION-DEPTH FACTOR

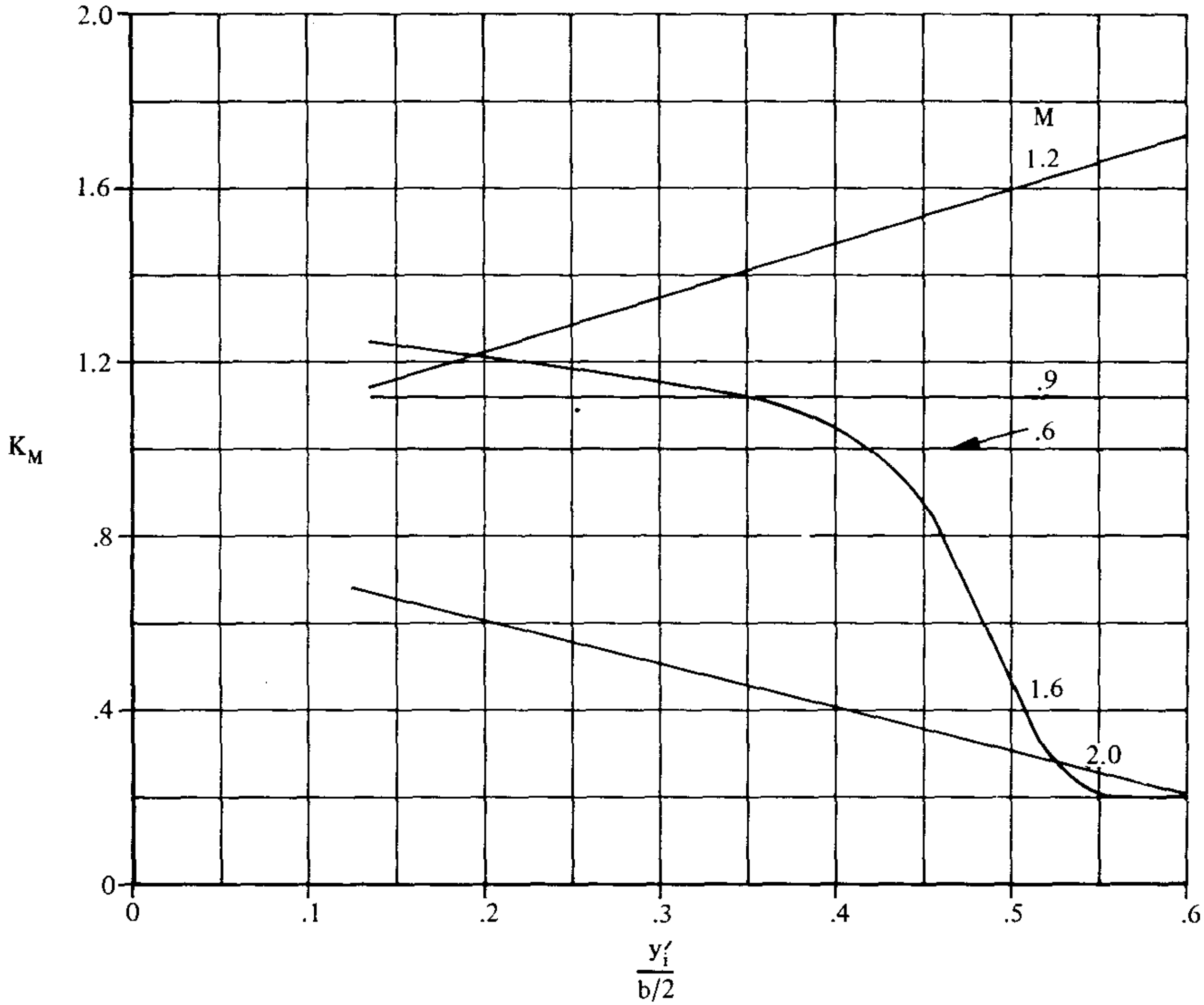


FIGURE 3.4-16 SIDE-FORCE MACH-EFFECT FACTOR

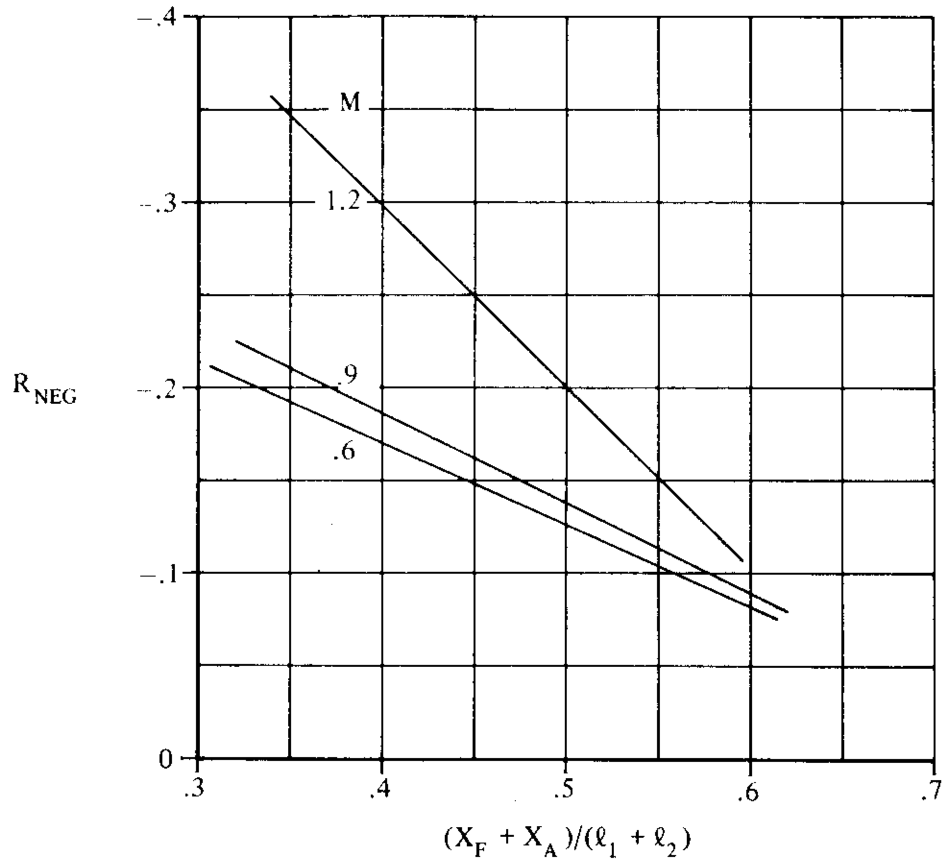


FIGURE 3.4-17 ADJACENT-STORE INTERFERENCE FACTOR

3.5 EFFECT OF EXTERNAL STORES ON AIRCRAFT YAWING MOMENT

A method is presented in this section for estimating the increment in aircraft yawing moment due to external-store installations. For symmetrically-loaded configurations, the increment is primarily due to sideslip. The incremental yawing moment due to asymmetrical loading is composed of a moment due to sideslip and a moment due to drag differential. The moment due to drag differential can be estimated by multiplying the incremental drag coefficient due to the store installation (which may be computed from Section 3.2) by the moment arm from the c.g. to the spanwise location of the installation. The method presented in this section predicts an incremental change in the yawing-moment-due-to-sideslip derivative, ΔC_{n_β}, which can be added to the clean aircraft C_{n_β} to obtain the aircraft-with-stores C_{n_β}.

The Datcom Method is taken from Reference 1 and is empirical in nature. The method requires that the incremental side-force data be provided by the user or computed by the method of Section 3.4. The method is limited to the store-loading configurations and Mach-number ranges presented in Table 3.5-A.

The Datcom Method is applicable to mixed loading configurations obtained by combining two or more loadings specified in Table 3.5-A. The method was developed from symmetrically-loaded-stores data and is therefore limited primarily to symmetrically-loaded configurations. However, certain asymmetric configurations can be treated by the method.

The prediction method was developed from data based on an angle of attack of 5°. No method is provided to account for the effect of angle-of-attack change on yawing moment, but the method is considered to be valid throughout the normal cruise angle-of-attack range.

TABLE 3.5-A

LOADING AND MACH-NUMBER LIMITATIONS

Mounting Location	Carriage Mode	Mount/Loading	Mach-Number Range
Wing	Single	Pylon – Empty	0.6 → 2.0
		Pylon – Store	
	Multiple	Pylon – Fully-Loaded MER	0.6 → 1.6
		Pylon – Fully-Loaded TER	
Fuselage	Single	Tangent	0.6 → 2.0
		Pylon – Store	
	Multiple	Pylon – Fully-Loaded MER	0.6 → 1.6

The method is subject to the following additional general limitations and assumptions:

1. The method has been verified for the Mach-number ranges given in Table 3.5-A. Caution should be used in extrapolating the empirical curves beyond the given Mach-number ranges.

2. The method has not been verified for configurations in which flaps, slats, or other flow-disrupting devices are deployed.

3. The store shape is essentially symmetrical with no major shape protuberances.

4. The data base used in deriving the method relied heavily on swept-wing tactical-combat-aircraft wind-tunnel data.

5. No tail effects are included.

6. The method is applicable for sideslip angles less than 8°.

The method is based on the premise that yawing moment is the product of the side force and a moment arm from the point of force application to a reference point. Lift and drag effects are neglected. The method is applicable to asymmetric configurations for which the sidewash change due to angle of attack is zero and fuselage effects are negligible.

The yawing-moment-derivative increment is composed of a basic contribution due to the store installations and a contribution due to interference between adjacent installations (when separation distance is small).

A. SUBSONIC

DATCOM METHOD

The increment in C_{n_β} (based on wing reference area and span) due to external stores is given by

$$\Delta C_{n_\beta} = \frac{1}{S_W b_W} \left\{ \sum_{i=1}^{N_I} \left(\frac{1}{2} Y_{B_\beta} \frac{\ell_m}{12} \right)_i + \sum_{j=1}^{N_P} \left[\frac{1}{2} Y_{A_\beta} \left(\frac{\ell_{m_1}}{12} + \frac{\ell_{m_2}}{12} \right) \right]_j \right\} \qquad 3.5\text{-a}$$

where

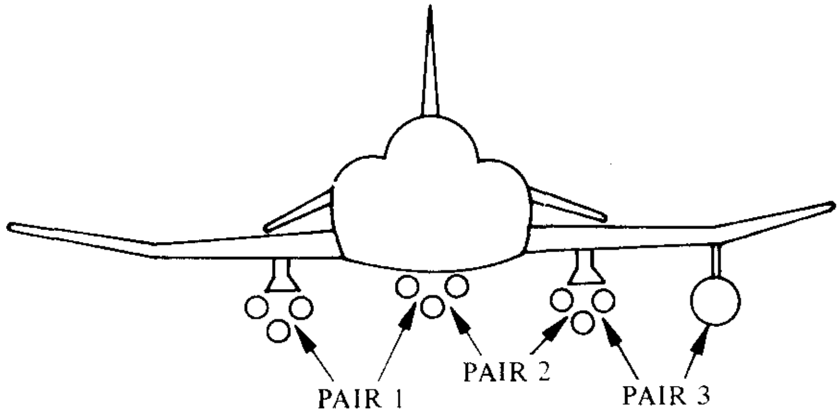
S_W is the wing reference area (ft^2).

b_W is the wing span (ft).

N_I is the total number of store installations on the aircraft.

Y_{B_β} is the basic side-force contribution (ft^2/deg) per degree sideslip due to a symmetrical pair of external-store installations, obtained from Section 3.4.

N_P is the total number of pairs of adjacent-store installations carried. (See Sketch (a).)



SKETCH (a)

Y_{A_β} is the side-force contribution (ft^2/deg) per degree sideslip due to interference effects from a pair of adjacent-external store installations, obtained from Section 3.4. This term should only be used for single-store installations placed at approximately equal distances below the wing, with minimum lateral separation of 25 to 60 inches between store surfaces of adjacent installations.

ℓ_m, ℓ_{m_1}, ℓ_{m_2} are moment arms (in.) from the moment reference point to the effective point of application of the side-force increment due to external stores, positive in the aft direction. The moment arm for the first of the pair of adjacent installations is ℓ_{m_1}, the second of the pair is ℓ_{m_2}. The value of ℓ_m is given by

$$\ell_m = (FS)_{ref} - [(FS)_{LE} + \ell_x] \qquad 3.5\text{-b}$$

where

$(FS)_{ref}$ is the fuselage station (in.) of the moment reference point.

$(FS)_{LE}$ is the fuselage station (in.) of the nose of the most forward store on the installation or the leading edge of the pylon for the empty pylon case.

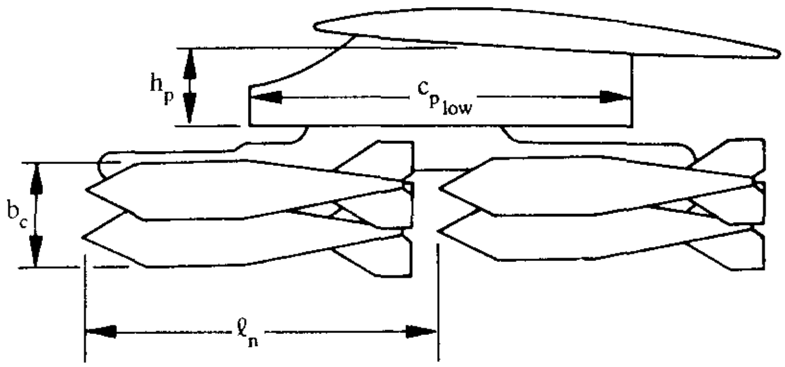
ℓ_x is the longitudinal distance (in.) from $(FS)_{LE}$ to the point of side-force application, positive aft. This term is a function of installation type, and is calculated below for various configurations.

Case 1: Wing-Mounted Empty Pylon

$$\ell_x = 0.25\, c_{p_{low}} \qquad 3.5\text{-c}$$

where

$c_{p_{low}}$ is the bottom-pylon-chord length (in.). (See Sketch (b).)



SKETCH (b)

Case 2: Wing- or Fuselage-Pylon-Mounted Single Store

$$\ell_x = \frac{\ell_P B_P + \ell_{SB} B_{SB} + \ell_{SF} B_{SF}}{B_P + B_{SB} + B_{SF}} \qquad 3.5\text{-d}$$

where

ℓ_P is the pylon moment arm (in.) given by

$$\ell_P = 0.25\, c_{p_{low}} \qquad 3.5\text{-e}$$

where $c_{p_{low}}$ is defined above for Case 1.

B_P is the pylon contribution given by

$$B_P = 0.15 \left(\frac{h_p}{12}\right)^2 \qquad 3.5\text{-f}$$

where

h_p is the average pylon height (in.) shown in Sketch (b).

ℓ_{SB} is the store-body moment arm (in.) given by

$$\ell_{SB} = 0.15\, \ell_S \qquad 3.5\text{-g}$$

where

ℓ_S is the store-body length (in.).

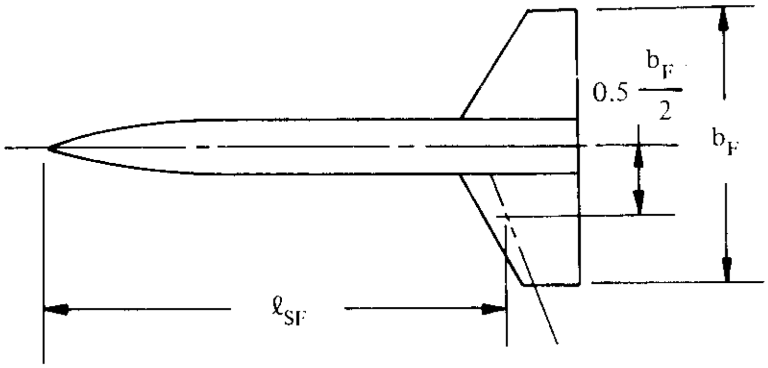
B_{SB} is the store-body contribution given by

$$B_{SB} = 0.09 \left(\frac{d_S}{12}\right)^2 \qquad 3.5\text{-h}$$

where

d_S is the maximum store diameter (in.).

ℓ_{SF} is the longitudinal distance (in.) from the store nose to the intersection of the store-fin quarter chord and the store-fin 50-percent semispan. (See Sketch (c).)



SKETCH (c)

B_{SF} is the store-fin contribution given by

$$B_{SF} = 0.082 \left(\frac{b_F}{12}\right)^2 \quad \text{for + or x type fins} \qquad 3.5\text{-i}$$

or

$$B_{SF} = 0.107 \left(\frac{b_F}{12}\right)^2 \quad \text{for V type fins} \qquad 3.5\text{-j}$$

where

b_F is the store-fin span (ft) shown in Sketch (c). (For V fins, the total span of the actual fin and its mirror image.)

Case 3: Wing- or Fuselage-Pylon-Mounted Fully-Loaded MER

$$\ell_x = \frac{(0.933)\, \ell_P B_P + 0.5\, \ell_{EM}\, (0.0325) + 0.5\, \ell_S B_{FSC} + \ell_{ASC} B_{ASC}}{B_P + 0.325 + B_{FSC} + B_{ASC}} \qquad 3.5\text{-k}$$

where

ℓ_P is given by Equation 3.5-e.

B_P is given by Equation 3.5-f.

ℓ_{EM} is the length of the empty MER (in.).

ℓ_S is the store-body length (in.).

B_{FSC} is the forward-store-cluster contribution given by

$$B_{FSC} = 0.0666 \left(\frac{b_c}{12}\right)^2 \left(\frac{b_f}{d_S}\right)^2 \qquad 3.5\text{-}\ell$$

where

b_c is the maximum vertical span (in.) of the side projection of the store cluster in a vertical plane, excluding protruding fins. (See Sketch (b).)

b_F and d_S are defined above in Case 2.

ℓ_{ASC} is the aft-store-cluster moment arm given by

$$\ell_{ASC} = 0.5\,\ell_S + \ell_n \qquad 3.5\text{-m}$$

where

ℓ_n is the longitudinal distance (in.) from the store nose of the forward cluster to the store nose of the aft cluster. (See Sketch (b).)

B_{ASC} is the aft-store-cluster contribution given by

$$B_{ASC} = R_{LC} B_{FSC} \qquad 3.5\text{-n}$$

where

B_{FSC} is given by Equation 3.5-ℓ.

R_{LC} is an aft-store-cluster lateral-clearance factor obtained from Figure 3.5-12 as a function of d_S the maximum store diameter.

Case 4: Wing-Pylon-Mounted Fully-Loaded TER

$$\ell_x = \frac{(0.80)\ \ell_P B_P + 0.5\ \ell_{ET}\ (0.182) + 0.5\ \ell_S B_{FSC}}{B_P + 0.182 + B_{FSC}} \qquad 3.5\text{-o}$$

where

ℓ_P is given by Equation 3.5-e.

B_P is given by Equation 3.5-f.

ℓ_{ET} is the length of the empty TER (in.).

B_{FSC} and ℓ_S are defined above in Case 3.

Case 5: Fuselage-Tangent-Mounted Single Store

$$\ell_X = \frac{\ell_{SB} B_{SB} + \ell_{SF} B_{SF}}{B_{SB} + B_{SF}} \qquad 3.5\text{-p}$$

where

ℓ_{SB} is given by Equation 3.5-g.

B_{SB} is given by Equation 3.5-h.

ℓ_{SF} is defined previously in Case 2.

B_{SF} is given by Equations 3.5-i and 3.5-j.

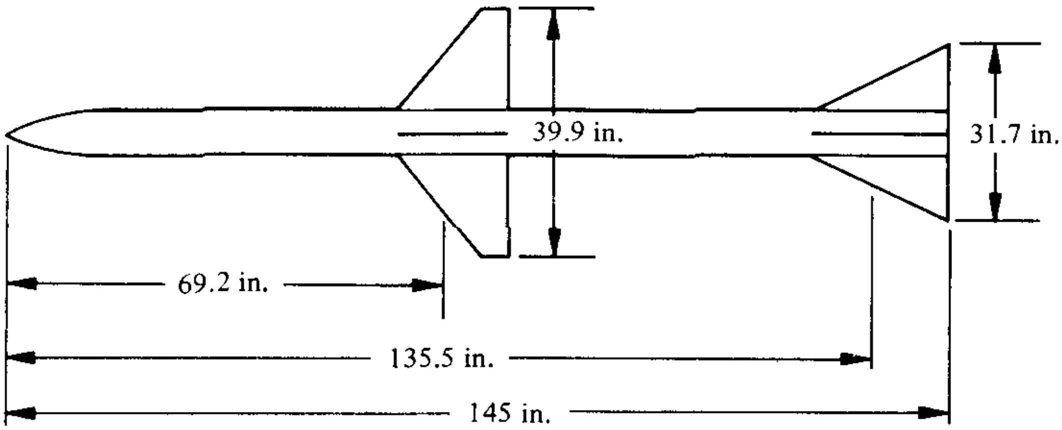
Reference 1 indicates that the method nominally results in average prediction errors of 20 percent from the actual yawing-moment increment. The percent error is highly dependent upon the distance from the aircraft center of gravity to the point of side-force application. When the side force acts through a point near the center of gravity, the percent error may be large even though the moment error is small. A comparison of test data with results calculated by this method is presented in Table 3.5-B. Additional comparisons of test and calculated results are found in Reference 1.

Sample Problem

Given: A swept-wing fighter aircraft from Reference 3 with single pylon-mounted air-to-air missiles mounted on each wing.

Aircraft Data:

$S_W = 530\ \text{ft}^2$ $\qquad b_W = 38.67\ \text{ft}$ $\qquad (FS)_{ref} = 317.0\ \text{in.}$



Store Data:

d_S = 8 in. $\qquad \ell_S$ = 145 in. $\qquad b_F$ (FWD) = 39.9 in.

b_F (AFT) = 31.7 in. $\qquad \ell_{SF}$ (FWD) = 69.2 in. $\qquad \ell_{SF}$ (AFT) = 135.5 in.

Installation Data:

$c_{p_{low}}$ = 113.8 in. $\qquad h_p$ = 18 in. $\qquad (FS)_{LE}$ = 182.0 in.

Additional Data:

M = 0.6 $\qquad \alpha = 5^o \qquad \Delta C_{Y_\beta} = -0.0015$ per deg

Compute:

Find ℓ_x for each installation. (Only one side need be computed since the installations are symmetrical.) For a wing-pylon-mounted single store:

$$\ell_P = 0.25\, c_{p_{low}} = (0.25)(113.8) = 28.45 \text{ in.} \qquad \text{(Equation 3.5-e)}$$

$$B_P = 0.15\left(\frac{h_p}{12}\right)^2 = (0.15)\left(\frac{18}{12}\right)^2 = 0.3375 \qquad \text{(Equation 3.5-f)}$$

$$\ell_{SB} = 0.15\, \ell_S = (0.15)(145) = 21.75 \text{ in.} \qquad \text{(Equation 3-5-g)}$$

$$B_{SB} = 0.09\left(\frac{d_S}{12}\right)^2 = (0.09)\left(\frac{8}{12}\right)^2 = 0.0400 \qquad \text{(Equation 3.5-h)}$$

Since there are two sets of fins on this store, both sets are accounted for in the computation.

For the forward set of fins,

$$\ell_{SF} = 69.2 \text{ in.}$$

$$B_{SF} = (0.082)\left(\frac{b_F}{12}\right)^2 = (0.082)\left(\frac{39.9}{12}\right)^2 = 0.907 \text{ ft}^2 \qquad \text{(Equation 3.5-i)}$$

For the aft set of fins,

$$\ell_{SF} = 135.5 \text{ in.}$$

$$B_{SF} = (0.082)\left(\frac{b_F}{12}\right)^2 = (0.082)\left(\frac{31.7}{12}\right)^2 = 0.572 \qquad \text{(Equation 3.5-i)}$$

$$\ell_x = \frac{\ell_P B_P + \ell_{SB} B_{SB} + \ell_{SF} B_{SF}}{B_P + B_{SB} + B_{SF}} \qquad \text{(Equation 3.5-d)}$$

$$= \frac{(28.45)(0.338) + (21.75)(0.0400) + (69.2)(0.907) + (135.5)(0.572)}{0.338 + 0.0400 + 0.907 + 0.572}$$

$$= 81.2 \text{ in.}$$

Find ℓ_m :

$$\ell_m = (FS)_{ref} - [(FS)_{LE} + \ell_x] \qquad \text{(Equation 3.5-b)}$$

$$= 317.0 - [182.0 + 81.2]$$

$$= 53.8 \text{ in.}$$

Since there are no pairs of adjacent store installations, ℓ_{m_1} and ℓ_{m_2} are not computed.

Find Y_{B_β} and Y_{A_β}:

Y_{B_β} and Y_{A_β} are estimated by the method of Section 3.4.

$Y_{A_\beta} = 0$ (no adjacent store installations)

Since ΔC_{Y_β} is given, Y_{B_β} can be computed from Equation 3.4-a.

$$\Delta C_{Y_\beta} = \frac{1}{S_W}\left[\sum_{i=1}^{N_I} \frac{1}{2}\left(Y_{B_\beta}\right)_i + \sum_{j=1}^{N_P}\left(Y_{A_\beta}\right)_j\right] \qquad \text{(Equation 3.4-a)}$$

Recalling that $Y_{A_\beta} = 0$ and that there are two installations symmetrically placed,

$$\Delta C_{Y_\beta} = \frac{1}{S_W}(2)\left(\frac{1}{2}\right)Y_{B_\beta}$$

$$Y_{B_\beta} = S_W \, \Delta C_{Y_\beta}$$

$$= (-0.0015)(530)$$

$$= -0.795 \text{ ft}^2/\text{deg}$$

Find ΔC_{n_β}:

$$\Delta C_{n_\beta} = \frac{1}{S_W b_W}\left\{\sum_{i=1}^{N_I}\left(\frac{1}{2}\, Y_{B_\beta} \frac{\ell_m}{12}\right)_i + \sum_{j=1}^{N_P}\left[\frac{1}{2}\, Y_{A_\beta}\left(\frac{\ell_{m_1}}{12} + \frac{\ell_{m_2}}{12}\right)\right]_j\right\} \qquad \text{(Equation 3.5-a)}$$

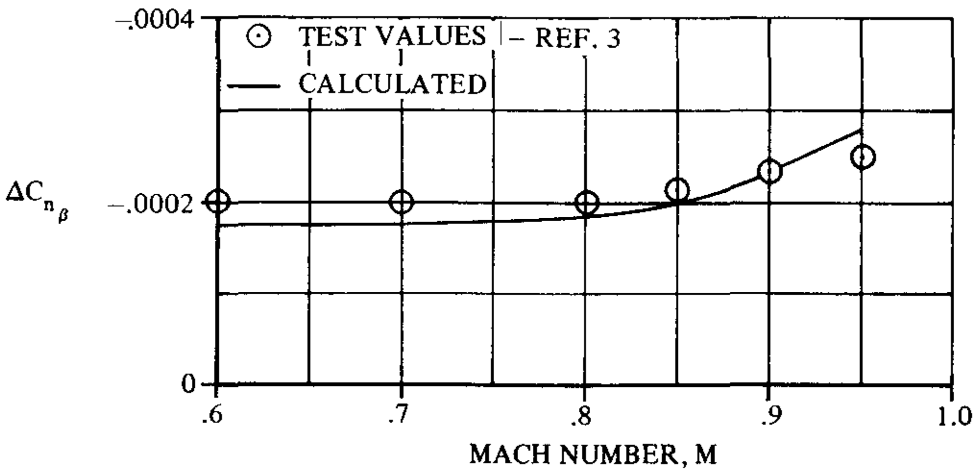
Since $Y_{A_\beta} = 0$, the second term in the above equation drops out. Since the store installations are symmetrical, the above equation reduces to

$$\Delta C_{n_\beta} = (2)\frac{1}{S_W b_W}\left(\frac{1}{2}\, Y_{B_\beta} \frac{\ell_m}{12}\right)$$

$$= \frac{2}{(530)(38.67)}\,\frac{1}{2}\,(-0.795)\left(\frac{53.8}{12}\right)$$

$$= -0.000174 \text{ per deg}$$

Additional values of ΔC_{n_β} at other Mach numbers are shown in comparison to test data from Reference 1 in Sketch (d).



SKETCH (d)

B. TRANSONIC

The method presented in Paragraph A of this section is also valid in the transonic speed range. The user is cautioned that the expected accuracy of the method is less than that expected in the subsonic speed range. A comparison of test data with results calculated by this method at transonic speeds is presented in Table 3.5-B.

C. SUPERSONIC

The method presented in Paragraph A of this section is also valid in the supersonic speed range up to a Mach number of 1.6 to 2.0 as indicated in Table 3.5-A. The maximum Mach numbers provided in the figures of Section 3.4 should indicate the levels to which the method is substantiated by Reference 1. Caution should be used when extrapolating the data beyond the Mach-number range provided in the figures. A comparison of test data with results calculated by this method at supersonic speeds is presented in Table 3.5-B.

REFERENCES

1. Gallagher, R. D., Jimenez, G., Light, L. E., and Thames, F. C.: Technique for Predicting Aircraft Aerodynamic Effects Due to External Stores Carriage. AFFDL-TR-75-95, Volumes I and II, 1975. (U)

2. Watzke, R. E.: Aerodynamic Data for Model TA-4F Operational Flight Trainer, McDonnell Douglas Corporation Rept. DAC-67425, 1968. (U)

3. Bonine, W. J., et al: Model F/RF-4B-C Aerodynamic Derivatives. McDonnell Douglas Corporation Rept. 9842, 1964 (Rev. 1971). (U)

TABLE 3.5-B

SUBSONIC AND SUPERSONIC EXTERNAL-STORE YAWING MOMENT DATA SUMMARY AND SUBSTANTIATION

Ref	Loading Description	α (deg)	M	ΔC_{n_β} calc (per deg)	ΔC_{n_β} test (per deg)	ΔC_{n_β} calc-test (per deg)
2	Wing Station Mounting	5	0.6	0.00048	−0.00015	0.00063
	Left Inboard Pylon-Mounted Single: 300-gal tank		0.8	0.00049	−0.00015	0.00064
	Right Inboard Pylon-Mounted Single: 300-gal tank		0.9	0.00053	−0.00015	0.00068
			0.95	0.00054	−0.00035	0.00089
3	Wing Station Mounting	5	0.6	−0.00017	−0.00020	0.00003
	Left Inboard Pylon-Mounted Single: Missile		0.8	−0.00019	−0.00020	0.00001
	Right Inboard Pylon-Mounted Single: Missile		0.9	−0.00023	−0.00023	0
			0.95	−0.00028	−0.00025	−0.00003
			1.2	−0.00032	−0.00045	0.00013
			1.6	−0.00023	−0.00023	0
			2.0	−0.00023	−0.00023	0

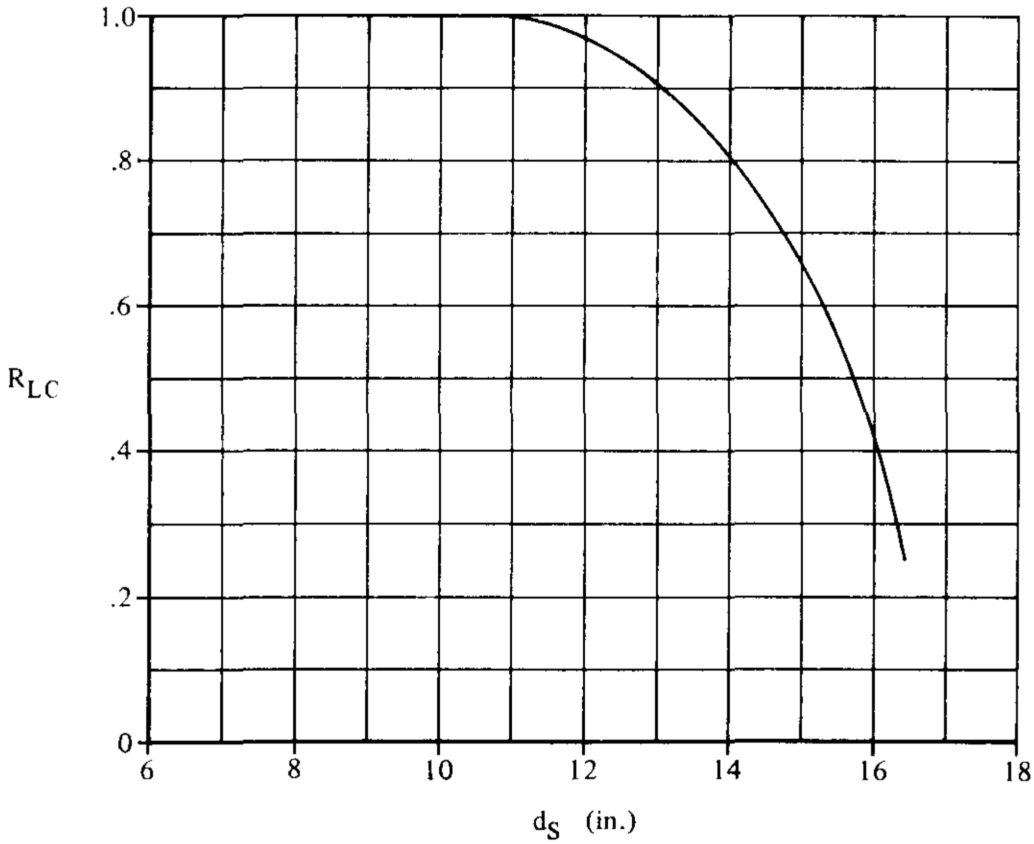


FIGURE 3.5-12 AFT-STORE-CLUSTER LATERAL-CLEARANCE FACTOR

3.6 EFFECT OF EXTERNAL STORES ON AIRCRAFT ROLLING MOMENT

No Datcom Method is provided to estimate the effect of external stores on aircraft rolling moment. No suitable general methods have been developed which provide satisfactory results for a wide range of loading configurations. The user may consult the references cited in Section 3 for available information on prediction of rolling moments.