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RESEARCH MEMORANDUM

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RESUME OF WIND-TUNNEL DATA ON THE EFFECT

OF EXTERNAL STORES ON STABILITY OF

MODELS OF MILITARY AIRPLANES

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CLASSIFICATION CANCELLED

Authority J. W. Crowley Date 12/14/53

E.O. 10501

By mHA 1/19/54 See NACA

R 42209

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

December 19, 1946

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

RÉSUMÉ OF WIND-TUNNEL DATA ON THE EFFECT OF EXTERNAL STORES ON STABILITY OF MODELS OF MILITARY AIRPLANES

By H. Norman Silvers and Raymond D. Vogler

SUMMARY

A study has been made of static wind-tunnel data on the effects of external stores (tanks, torpedoes, bombs, and radar domes) on the stability of military airplanes. A summary, in tabular form, of the available data is presented.

The data obtained indicate that at Mach numbers below 0.4 the effects of external stores on static longitudinal stability were small but may not be negligible. Although data were meager for Mach numbers above 0.4, the results indicated that wing-tip tanks which were well faired to the wing contour caused reasonably small changes in static longitudinal stability. The available data were insufficient to estimate the general effects of external stores on lateral stability. For one model, however, the adverse effect of stores on directional stability, although small, was of the order of magnitude of the directional stability of a fighter airplane considered acceptable for military service.

INTRODUCTION

Limitations of space inside current long-range, heavily armed, high-speed airplanes have resulted in the practice of installing part of the auxiliary equipment on the exterior of the airplane. External installation of auxiliary equipment facilitates maintenance and results in a more flexible arrangement than internal installation of equipment. Such installations have, in certain cases, adversely altered the aerodynamic characteristics of the airplane. In an effort to overcome difficulties arising in flight because of these external installations, the NACA has undertaken a research program to determine the effects of external stores (tanks, torpedoes, bombs, and radar domes) on the aerodynamic characteristics of airplanes.

One of the first projects in this program is a general résumé of the effects of external stores on stability of models of military airplanes.

A brief summary of the various data obtained in static wind-tunnel tests at the Langley Memorial Aeronautical Laboratory and the Ames Aeronautical Laboratory on the effects of external stores on stability is presented herein. The results are based upon static wind-tunnel tests of various service and research airplane models.

COEFFICIENTS AND SYMBOLS

Δn_p change in elevator-fixed neutral-point location due to external store, percent M.A.C.; positive when longitudinal stability is increased by store

ΔC_D change in drag coefficient due to external store; positive when store increases drag

ΔC_{n_ψ} change in directional stability parameter due to external store; positive when store decreases stability

ΔC_{l_ψ} change in lateral stability parameter; positive when external store increases effective dihedral

C_L lift coefficient

$\bar{c}$ wing mean aerodynamic chord (M.A.C.)

l length of external store

M Mach number (V_o/a_o)

V_o free-stream velocity, feet per second

a_o velocity of sound in free stream, feet per second

Subscripts:

ψ partial derivative of coefficient with respect to yaw

o free stream

PRESENTATION OF DATA

The analysis is based upon results of wind-tunnel tests presented in references 1 and 2 and upon other data obtained at the Langley and Ames Laboratories and represents the greater part of the data on the effect of external stores on stability obtained by the NACA to date This analysis is confined to wind-tunnel data obtained from tests of models with propellers either removed or windmilling and with the flaps undeflected. The results are presented as increments of n_p, C_D, C_{n_ψ}, and C_{l_ψ}. These increments were determined, at any particular lift coefficient, by subtracting the value obtained without the external store from the value obtained with the store. The results of this analysis are summarized in tables I and II. The results presented in table I are based upon data obtained at Mach numbers below 0.4 and those in table II, upon data above $M = 0.4$. Such a division seems appropriate, because the data taken specifically to determine compressibility effects begin at about $M = 0.4$. Also included in these tables are pertinent geometric characteristics of the installations. Elevator-fixed neutral points over a lift-coefficient range from $C_L = 0.1$ to $C_L = 1.0$ were determined by methods similar to those of reference 3. The range of Δn_p shown in tables I and II is determined by the maximum decrease or increase in stability due to external stores. The average drag increments are presented for the range of lift coefficient from $C_L = 0$ to $C_L = 0.3$. The average increments (Δn_p, ΔC_D, ΔC_{n_ψ}, and ΔC_{l_ψ}) presented in tables I and II were obtained by a graphical method in which a mean value of the incremental coefficients was determined throughout the lift range. This method was used since data that are unreliable because of partial stalling of the model at high lift coefficients affect these mean values only slightly. This method is therefore believed to give a clearer general conception of the effects of external stores on stability than does consideration of the maximum decrease or increase in stability.

DISCUSSION

Longitudinal stability.- The results shown in table I indicate that at Mach numbers below 0.4 the effect of external stores on static longitudinal stability, though small, may not be negligible. Only three of the installations showed an average change in stability greater than the expected accuracy (±1.5 percent M.A.C.) of neutral-point determination Although data for Mach numbers above 0.4 are meager (table II), the results indicated that wing-tip tanks that were well faired to the wing contour caused reasonably small changes in static longitudinal stability. A very appreciable stabilizing effect was experienced at higher Mach numbers, however, when two 500-pound bombs were attached with drop hooks and sway braces to the undersurface of the wing. This change in stability is probably associated with the large increase in drag due to the bomb installations with an increase in Mach number. Pressure distributions taken at a low Mach number indicate that the critical Mach number of such installations may be as low as 0.6.

Lateral stability.- Insufficient data are available at present to estimate the general effects of external stores on lateral stability at Mach numbers below 0.4. No data at Mach numbers above 0.4 are available. It should be noted, however, that the value of ΔC_{n_ψ} of 0.00030 contributed by the wing tanks of one model (table I) is of the order of magnitude of the total C_{n_ψ} of a fighter airplane considered acceptable for military service. Such an installation on this fighter airplane would actually cause directional instability.

CONCLUSIONS

Analysis of a collection of data from static wind-tunnel tests on the effects of external stores (tanks, torpedoes, bombs, and radar domes) on the stability of airplane models indicated the following conclusions:

1. At Mach numbers below 0.4, the effect of external stores on static longitudinal stability, although small, may not be negligible.

2. Although data for Mach numbers above 0.4 were meager, the results indicated that wing-tip tanks that were well faired to the wing contour caused reasonably small changes in static longitudinal stability.

3. The available data were insufficient to estimate the general effects of external stores on lateral stability. For one model, however, the adverse effect of stores on directional stability, although small, was of the order of magnitude of the directional

stability of a fighter plane considered acceptable for military service.

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REFERENCES

1. Pepper, Edward: Wind-Tunnel Tests of Several Arrangements of External Auxiliary Fuel Tanks on a Fighter-Type Airplane. NACA ACR, Aug. 1942.

2. Hanson, Frederick H., Jr.: The Effect of a Wing-Tip-Mounted Fuel Tank on the Aerodynamic Characteristics of a High-Speed Bomber Wing. NACA ACR No. 5H06, 1945.

3. Schuldenfrei, Marvin: Some Notes on the Determination of the Stick-Fixed Neutral Point from Wind-Tunnel Data. NACA RB No 3I20, 1943.

TABLE I.- EFFECTS OF EXTERNAL STORES ON STABILITY AT MACH NUMBERS BELOW 0.4

Item	Number and description	Mounting	$l/\bar{c}$	Range of Δn_p (percent M.A.C.)	Average Δn_p (percent M.A.C.)	Average ΔC_D	Average ΔC_{n_ψ}	Average ΔC_{l_ψ}	Model scale
Tank	One, 650 gal, semicircular faired to fuselage	Belly	2.47	-3.0 to 1.0	-0.4	0.0050	------	------	$\frac{1}{6}$
[a]Tank	One, 200 gal, rectangular; Two, 75 gal, rectangular	Belly; Wing	.65	-2.0 to 2.0	.7	.0055	------	------	$\frac{1}{2.75}$
[a]Tank	One, 300 gal, circular	Belly	1.90	-1.5 to 2.5	.1	.0020	-------	-------	$\frac{1}{2.75}$
Tank	One, 200 gal, circular	Belly	2.15	-.5 to 3.5	1.6	.0010	-------	0.00010	$\frac{1}{5}$
Tank	One, 150 gal, circular	Belly	1.41	-3.5 to 1.0	-1.5	.0040	-------	-------	Full
Tank	One, 150 gal, circular	Belly	1.50	-.5 to .8	.2	.0050	0.00009	.00012	$\frac{1}{5}$
[a]Tank	One, 150 gal, circular	Belly	1.51	-1.5 to 1.5	.2	.0020	-------	-------	$\frac{1}{2.75}$
Tank	One, 100 gal, circular	Belly	.88	-3.0 to 0	-1.0	.0035	-------	-------	$\frac{1}{2.75}$
Tank	Two, 600 gal, circular	Wing tip	1.34	-2.0 to .8	.8	-.0008	-------	-------	$\frac{1}{10}$
[b]Tank	Two, 600 gal, circular	Wing tip	1.34	-1.7 to 1.3	-.1	.0004	-------	-------	$\frac{1}{10}$
[b]Tank	Two, 600 gal, circular	Wing tip	1.39	-1.0 to 1.0	-.2	-.0004	-------	-------	$\frac{1}{10}$
Tank	Two, 300 gal, circular	Wing tip	1.06	-1.0 to 1.0	.3	-.0007	-------	-------	$\frac{1}{10}$
[b]Tank	Two, 300 gal, circular	Wing tip	1.10	-1.4 to 1.6	.1	.0005	-------	-------	$\frac{1}{10}$
[b]Tank	Two, 300 gal, circular	Wing tip	.87	-.9 to 1.8	.3	.0001	-------	-------	$\frac{1}{10}$
[b]Tank	Two, 300 gal, circular	Wing tip	1.06	-.8 to 1.1	0	.0004	-------	-------	$\frac{1}{10}$
Tank	Two, 250 gal, circular	Wing tip	1.66	-2.0 to -.5	-1.0	.0010	-.00008	.00035	$\frac{1}{5}$
Tank	Two, 300 gal, circular	Wing	1.82	-2.2 to 1.0	-1.8	.0045	.00011	-.00001	$\frac{1}{6}$
Tank	[c]Two	Wing	(c)	-5.5 to -1.5	-3.0	.0070	-------	-------	$\frac{3}{4}$
Tank	Two, 250 gal, circular	Wing	1.66	-3.5 to - .2	-1.2	.0070	.00012	-.00025	$\frac{1}{5}$
Tank	Two, 150 gal, circular	Wing	1.15	-1.0 to 1.0	-.3	-.0015	.00030	-.00020	.14
Tank	Two, 150 gal, circular	Wing	1.51	-2.0 to 1.0	-.8	.0020	-------	-------	$\frac{1}{2.75}$
Tank	Two, 75 gal, circular	Wing	.74	-----------	--------	--------	0	-------	.32
Torpedo	One, 21 in.	Belly	1.71	-0.5 to 2.0	.5	.0041	-------	-------	$\frac{1}{2.75}$
Torpedo	One, 21 in.	Belly	1.65	0 to .5	-.2	.0030	-------	-------	.15
Torpedo	Four, 21 in.	Wing	1.49	-1.0 to -.5	-.7	.0110	-------	-------	.30
Bomb	Two, 4000 lb	Wing	1.07	-1.0 to 0	-.2	.0090	-------	-------	.30
Bomb	Two, 1000 lb	Wing tip	.76	-1.7 to 1.7	.2	--------	.00006	-.00080	$\frac{1}{5}$
Bomb	One, 1000 lb	Wing (left)	.76	-1.0 to .2	-.2	--------	-.00006	.00010	$\frac{1}{5}$
Bomb	One, 1000 lb	Belly	.69	0 to 1.0	.3	.0070	-------	-------	.15
Bomb	Four, 500 lb	Wing	.61	-1.0 to 1.5	.7	--------	-.00003	-.00005	.2375
Bomb	Two, 500 lb	Wing	.57	-0.4	-.4	.0048	-------	-------	$\frac{3}{16}$
Bomb	Four, 300 lb	Wing	.52	0 to 1.5	.7	--------	-------	-------	.2375
Bomb	Four, 100 lb	Wing	.39	-1.5 to 2.0	.5	--------	-------	-------	.2375
Radar	-------------	Wing	.97	-3.8 to 2.0	-1.2	.0021	-------	-------	Full
Radar	-------------	Wing	.73	-1.0 to 1.7	-.1	.0005	-------	-------	$\frac{1}{3}$
Radar	-------------	Wing	.76	-.3 to 2.5	.3	.0055	-------	-------	$\frac{1}{5}$

[a]Reference 1.

[b]Reference 2.

[c]Geometric characteristics unavailable.

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TABLE II.- EFFECTS OF EXTERNAL STORES ON LONGITUDINAL STABILITY

AT MACH NUMBERS ABOVE 0.4

Item	Number and description	Mounting	$l/\bar{c}$	M	Range of Δn_p (percent M.A.C.)	Average Δn_p (percent M.A.C.)	Average ΔC_D	Model scale
[a]Tank	Two, 600 gal, circular	Wing tip	1.34	0.60	-2.0 to 4.5	0	-0.0013	$\frac{1}{10}$
				.65	-5.5 to 3.0	.7	-.0010	
				.70	-.5 to 2.3	.8	-.0005	
				.725	-1.0 to 3.0	.3	-.0002	
				.75	-1.0 to 3.0	.3	0	
				.775	1.0 to 2.5	1.8	.0010	
				.80	0 to 2.3	1.5	.0032	
				.825	-1.0 to 3.0	-.4	.0051	
				.85	-4.0 to 0	-1.0	.0096	
				.875	-4.5 to 4.0	2.0	.0150	
Tank	Two, 300 gal, circular	Wing tip	1.06	.60	-.8 to 2.5	1.0	-.0015	$\frac{1}{10}$
				.65	-4.0 to 1.5	0	-.0020	
				.70	-.6 to .2	-.3	-.0015	
				.725	-1.5 to 1.5	-.3	-.0012	
				.750	-5.0 to 2.0	1.3	-.0007	
				.775	-1.0 to 2.0	.8	0	
				.80	-1.3 to 1.5	0	.0012	
				.825	-1.0 to 3.0	.2	.0028	
				.85	-2.5 to .3	-.8	.0075	
				.875	-.5 to 4.0	3.0	.0115	
Tank	Two, 150 gal, circular	Wing	1.15	.50	-.9 to -.1	-.4	.0020	0.14
				.60	-.5 to -.1	-.3	.0038	
				.65	-1.5 to .3	-.8	.0066	
				.675	-1.2 to -.3	-.6	.0091	
				.70	-.3 to .4	.1	.0147	
				.725	0 to 3.7	1.8	.0325	
Bomb	Two, 500 lb	Wing	.57	.50	0.3	.3	.0040	$\frac{3}{16}$
				.60	.9 to .1	.3	.0073	
				.65	-.1 to 3.5	.8	.0090	
				.70	.5 to 10.0	4.7	.0135	
				.75	-.1 to 11.3	4.5	.0155	
				.80	-.3 to 18.7	8.5	.0287	

[a]Reference 2.

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