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RESEARCH MEMORANDUM

EFFECT OF WING-TANK LOCATION ON THE DRAG AND TRIM OF A SWEPT-WING MODEL AS MEASURED IN FLIGHT AT TRANSONIC SPEEDS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

Results of an exploratory free-flight investigation at zero lift of several rocket-powered drag research models equipped with wing tanks are presented for a Mach number range from about 0.50 to 1.15. The tanks, which were slender bodies of revolution, were mounted on 34° sweptback, nontapered wings of 2.7 aspect ratio. The tanks were directly attached to the wings in such a way that their center lines were positioned on or vertically displaced from the wing-chord plane for tip and inboard spanwise locations. The tanks positioned on the chord plane were also located more forward than were the vertically displaced tanks.

These data show that the test configuration with tanks located inboard on the chord line and in the forward position gave the least drag of the four configurations tested. The drag rise for this model followed very closely the drag rise of the tankless model. The strut-tank model from a previous paper (NACA RM L8H31a) had a higher drag and a drag rise occurring at a lower Mach number than any of the models tested in this investigation. The results of this investigation indicate that the tank location has a large effect on the total drag of the configuration. The data also indicate that the unsymmetrical models experienced a trim change in the Mach number range from 0.85 to 1.00.

INTRODUCTION

A need exists for experimental data in the transonic speed region for the prediction of drag characteristics of general wing-nacelle and external-stores combinations. The Langley Pilotless Aircraft Research Division has completed a preliminary program using rocket-powered research models from which the drag and rate of roll (a measure of trim change) resulting from various tank locations were recorded. This paper contains information obtained from investigations of models having untapered, 34° sweptback wings of 2.7 aspect ratio with bodies of revolution mounted at different positions on the wings. Configurations were tested with the tanks located at the tip and inboard, on and displaced from the chord plane. The tanks on the chord plane were located farther forward than the tanks which were displaced from the chord plane. The data are presented as plots of drag coefficient and wing-tip helix angle against Mach number. From these data the drag and an indication of trim changes resulting from the addition of the tanks can be determined. The results of this investigation are compared with data obtained in a previous investigation which used similar models with and without strut-mounted bodies of revolution (reference 1).

The average Reynolds number variation for the models tested in this investigation covers a range of from 2.9×10^6 at a Mach number of 0.5 to 8.69×10^6 at a Mach number of 1.20.

SYMBOLS

$\frac{pb}{2V}$	wing-tip helix angle, radians
p	rolling velocity, radians per second
b	total span of 25.73 inches
V	velocity along flight path, feet per second
C_D	total-drag coefficient based on exposed wing area of 200 square inches
C_{D_t}	drag coefficient of tanks based on frontal area of two tanks of 13.2 square inches
M	Mach number
A	aspect ratio, $\frac{b^2}{S}$
S	total wing area to center line of body, 248.22 square inches
R	Reynolds number based on wing chord of 9.647 inches

MODELS

The general arrangement of the drag research vehicles used in the present investigation is shown in figures 1 and 2 and photographs of the models are shown in figure 3. The basic model construction, described in reference 2, has been altered in the 102 B, 103 A and B, and 104 A and B models by the substitution of spinsonde noses, reference 3, for the ordinary wooden noses. The tanks were located on a 34° sweptback wing with NACA 65-009 airfoil section normal to the leading edge. The tanks, of wooden fabrication, were of similar design to those used on fighter-type aircraft and were attached to the wing in the relative positions indicated in figures 1 and 2. The tanks had a constant fineness ratio of 7.44 and the ratio of tank diameter to body diameter was 0.582. For convenience, the table in figure 1 shows the different tank locations for the four different arrangements.

Eight models were used in the investigation. Two models (102 A and B) had their tanks located at the wing tips with the chord line of the wing coinciding with the center line of the tank and with the ends of the tanks being flush with the trailing edge of the wing; two other models (120 A and B) had their tanks located at an inboard position with the ends of the tanks being flush with the trailing edge of the wing and with the center line of the tank coinciding with the chord line of the wing (these models will be referred to in this paper as the inboard-forward symmetrical models); two models (103 A and B) had their tanks located at the wing tips with the tanks located on opposite surfaces of the wing and with the trailing edge of the tanks extending behind the trailing edge of the wing; the final models (104 A and B) had their tanks located at an inboard position with the tanks located on opposite surfaces of the wing and with the trailing edge of the tanks extending behind the trailing edge of the wing. The tanks, which were mounted on opposite surfaces, were located in that manner in order that the models would maintain straight-line flight paths despite any trim changes that might be induced by the tanks and in order to allow a determination of the trim-change tendencies by the simple measurement of rolling velocity.

The models were propelled by 3.25-inch aircraft rocket motors which were contained within the fuselage. At a preignition temperature of 69° F, the rocket motors furnished approximately 2200 pounds of thrust for about 0.87 second.

TESTS

The models were flown at the Langley Pilotless Aircraft Research Station, Wallops Island, Va. The testing technique whereby drag-coefficient data are obtained has been adequately described in reference 4.

The accuracy of the drag coefficients is estimated to be ±0.002 at Mach numbers above 1.0 and ±0.003 at Mach numbers below 1.0. The accuracy of the Mach number is estimated to be within ±0.01.

The rolling velocity of each model and the resulting wing-tip helix angle $\frac{pb}{2V}$ were determined by the technique described in reference 3. The accuracy of the quantity $\frac{pb}{2V}$ is estimated to be within ±0.005 radian throughout the Mach number range. The erratic variation in $\frac{pb}{2V}$ above 0.9 Mach number in model 102 is not clearly understood.

The average Reynolds number of the eight models based on wing chord (9.647 inches) parallel to the body center line varied from 2.92×10^6 at a Mach number of 0.5 up to 8.69×10^6 at a Mach number of 1.20. A plot of Reynolds number against Mach number is shown in figure 4.

RESULTS AND DISCUSSION

Drag

The total-drag coefficient C_D and wing-tip helix angle $\frac{pb}{2V}$ are presented in figure 5 plotted against Mach number M for the models investigated. No drag data were obtained for one of the 104 models nor were there any $\frac{pb}{2V}$ data for either of the 120 models. Previous data have been obtained for the strut-tank model, a tankless model, and a wingless model; these data have been presented in reference 1 and are included in this paper for comparison. The curves for the strut-tank model and tankless model have been slightly modified by use of a later, more precise method of reducing flight-test data. The total-drag-coefficient curve for the wingless model has been included in figure 5 in order that the percent of wing-tank-combination drag which could be expected to be due to the wing alone may be estimated.

The curves shown in figure 5 indicate that the presence of the tanks caused the drag rise to occur at approximately 0.03 Mach number lower than the drag rise of the tankless model in all of the configurations investigated except the inboard-forward symmetrical case. For this configuration, the drag rise occurred approximately at the same Mach number as the drag rise of the tankless model. References 5 and 6 may partially explain why the inboard-forward symmetrical model gave the more favorable effect of the configurations tested. The results of those references indicated that locating the wing aft of the maximum diameter of a body gave less drag than a forward location.

An estimated tank-drag-coefficient curve for an isolated tank is presented in figure 6, which was obtained from a drag curve for a body of revolution, reported in reference 7, similar to that of the test tanks. The body in reference 7 was a fin-stabilized parabolic body of revolution with a cut-off stern. Its fineness ratio was 6, and its maximum diameter was located at 60 percent of body length. The fin and base drag was subtracted from the total drag of this body leaving the drag curve shown. It is believed that this curve represents a body which is sufficiently similar to the test tanks for comparative purposes.

The tank-drag coefficient due to the addition of the tanks, which included interference effects, was determined by the drag differences between the tank-on and tank-off configurations and is also shown in figure 6. This coefficient is based on the frontal area of two tanks. The variation of the drag-coefficient increment with the different models indicates the importance of tank location with respect to the wing and body in order to minimize tank drag. The inboard-forward symmetrical model tanks gave the most favorable drag increment of the four configurations investigated. The favorable effects of this tank location might not be realized if used in conjunction with another type body or wing. The drag increments for the models tested were much lower than that obtained from the strut-tank model from reference 1. The tanks were located on struts at approximately midspan; however, the tank-drag-coefficient curve of the strut-tank model included the drag due to the strut.

Trim Change

An indication of the trim changes due to the tanks is given by the variations of $\frac{pb}{2V}$ with Mach number presented in figure 5. The variations of $\frac{pb}{2V}$ with Mach number for the unsymmetrical models indicated that they experienced a trim change in the Mach number range from 0.85 to 1.00. The roll obtained at $M < 0.9$ for the symmetrically located tanks of model 102 is believed due to accidental asymmetries in the model; however, the erratic variation in $\frac{pb}{2V}$ at $M > 0.9$ for this model is not clearly understood.

CONCLUDING REMARKS

An exploratory rocket-powered flight investigation of drag research models with wing tanks has been conducted near zero lift for a Mach number range from 0.50 to 1.15. The tanks, which were slender bodies of revolution, were mounted on 34° sweptback, nontapered wings of 2.7 aspect ratio in varied positions. The addition of the tanks to the models increased the drag coefficient; however, the tanks on the inboard-forward symmetrical model produced the least increase in drag. Attachment of the tanks also caused the drag rise to occur at 0.03 lower Mach number in all models except the inboard-forward symmetrical model. The drag rise of this model followed very closely the drag rise of the tankless model. The data indicated that the location of the tanks has a marked effect on the total drag and also on the point at which the drag rise occurs in the Mach number range covered in this investigation. Although the inboard-forward symmetrical model gave the lowest drag of the configurations tested, it is quite possible that some other tank-wing-body combination would give even lower drag. The data also showed that the unsymmetrical models experienced a trim change in the Mach number range of 0.85 to 1.00.

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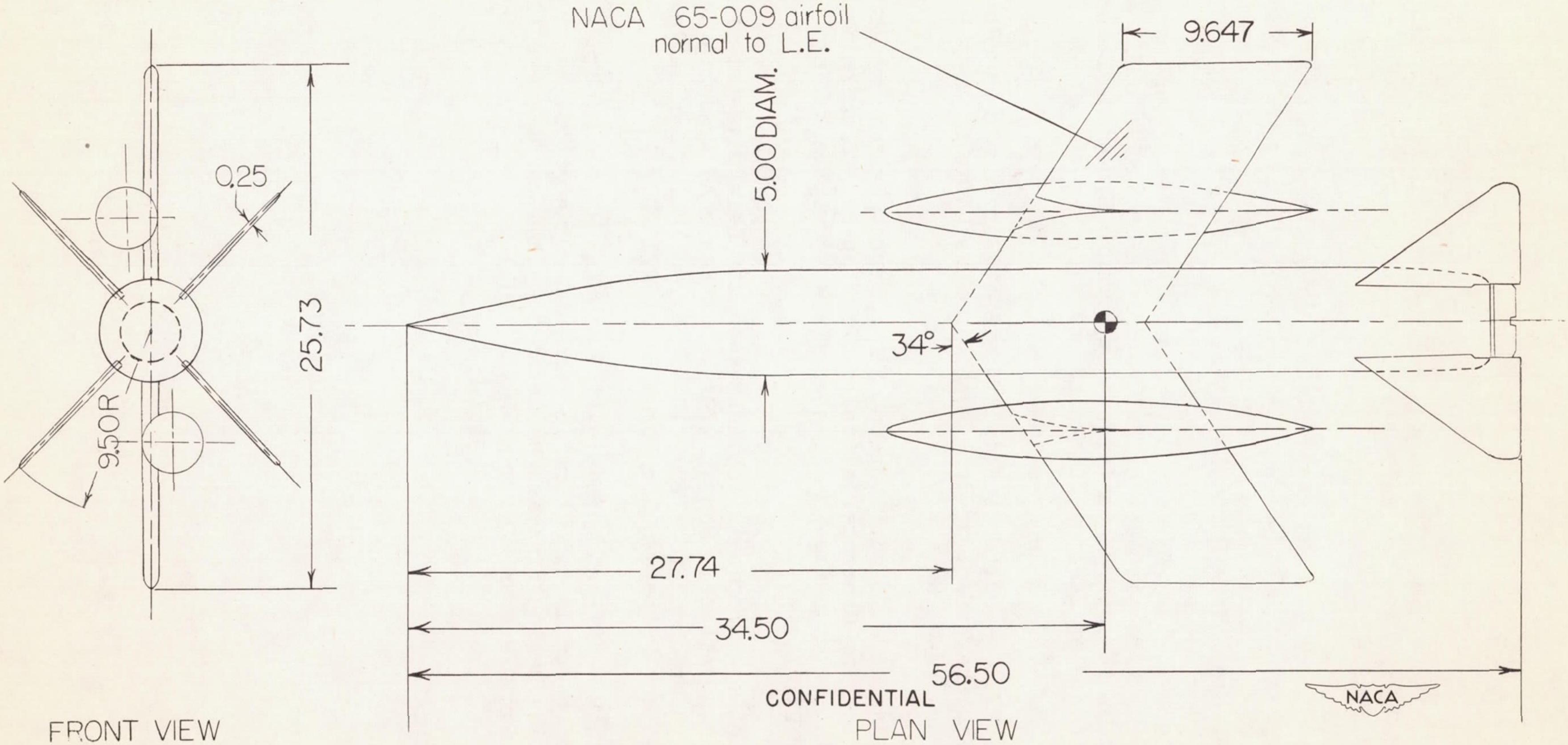
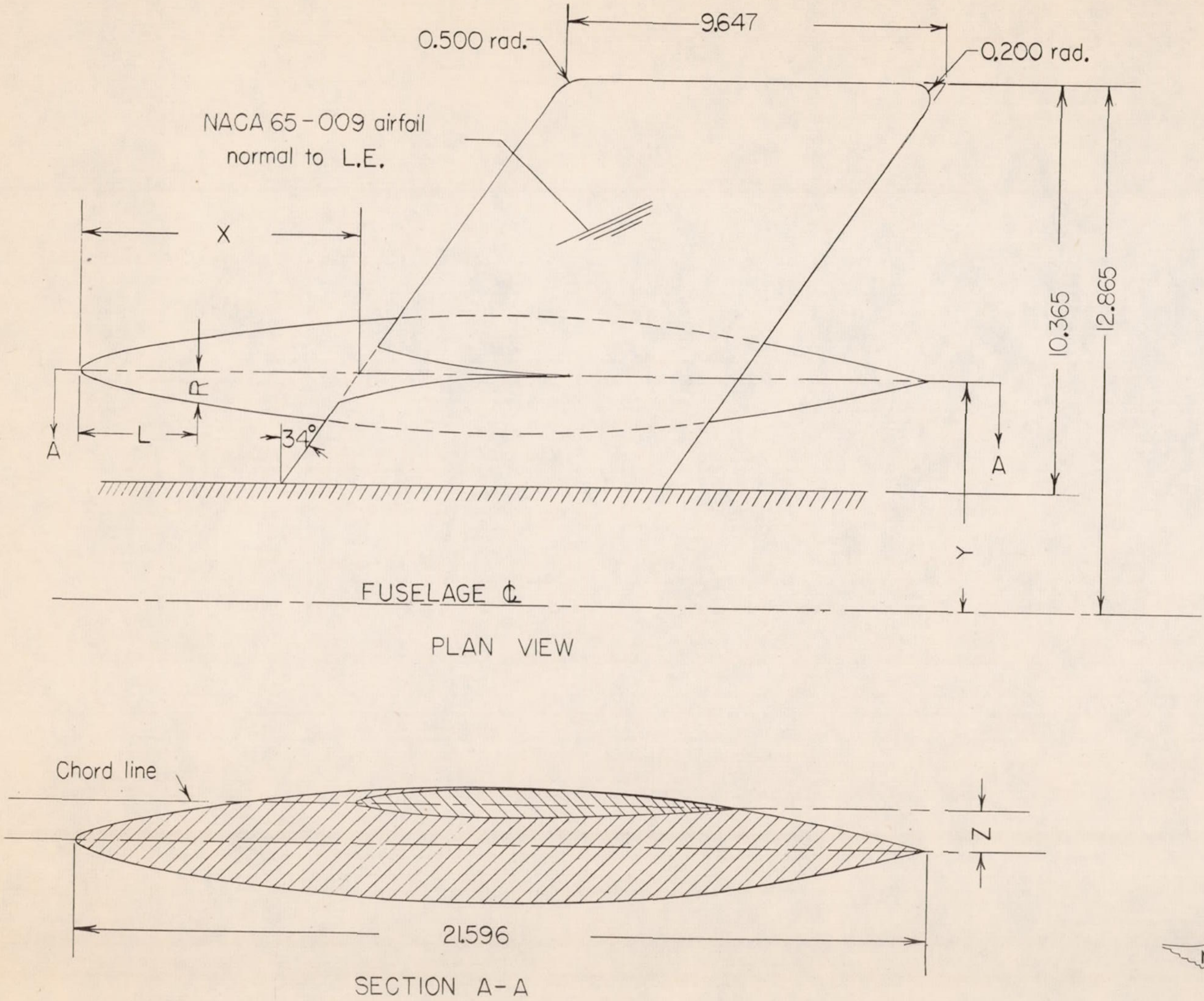


Figure 1.- General arrangement of drag research vehicle with wing tanks. All dimensions in inches.



TANK LOCATION				
MODEL	X	Y	Z	
			R.WING	L.WING
102	11.949	12.865	0	0
103	7.063	12.865	1.089	-1.089
104	7.063	5.329	-1.089	1.089
120	11.949	5.329	0	0

TANK COORDINATES			
L	R	L	R
0.083	0.1128	10.383	1.454
0.249	0.2014	10.798	1.453
0.415	0.2664	12.465	1.415
0.831	0.395	14.120	1.315
1.662	0.593	15.789	1.149
2.792	0.758	16.612	1.041
4.153	1.019	17.451	0.916
4.986	1.126	18.273	0.772
5.814	1.216	19.113	0.609
6.648	1.292	19.944	0.426
7.475	1.353	20.775	0.223
8.306	1.399	21.191	0.114
9.136	1.432	21.596	0.000
L.E. radius = 0.079			
T.E. radius = 0.020			

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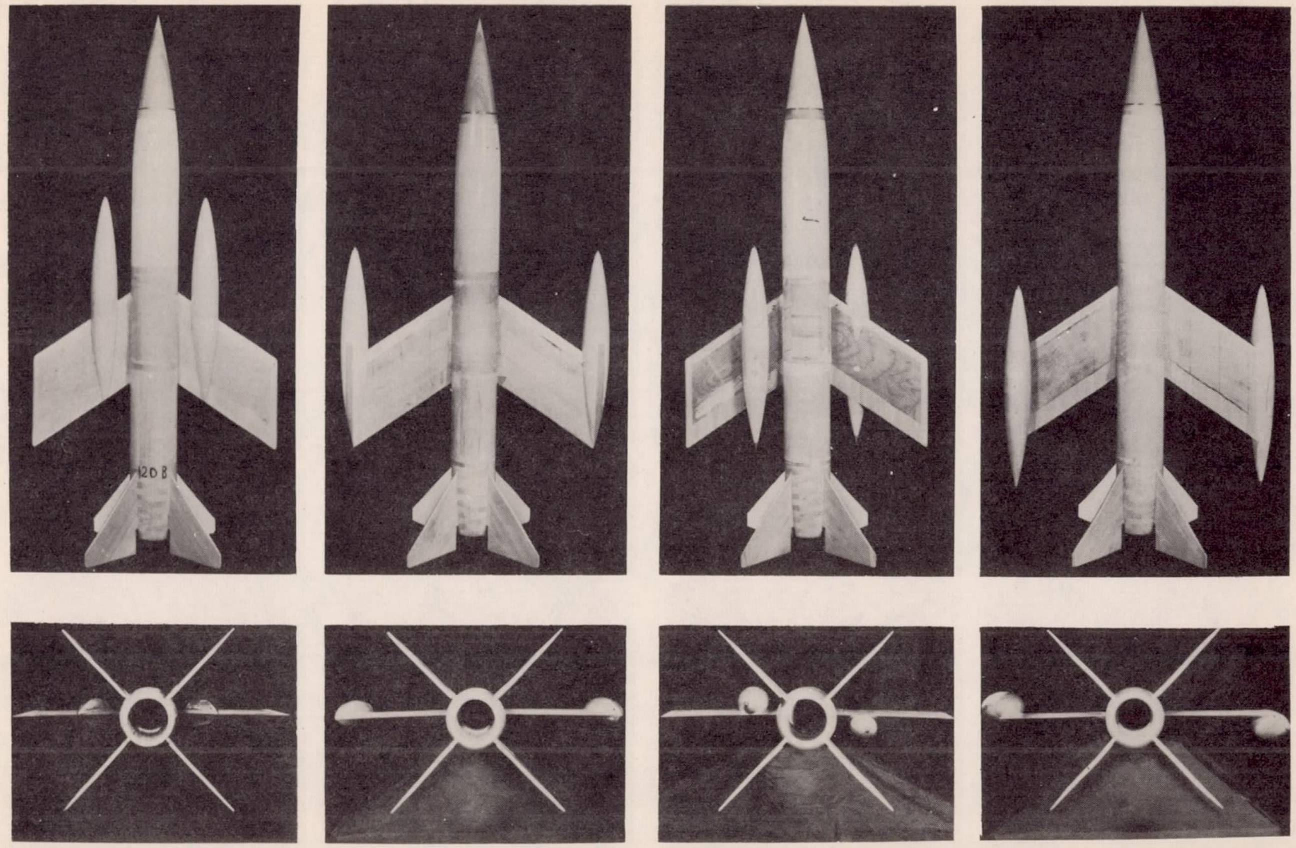
Figure 2.- Details of wing-tank installation on model. Tank fineness ratio = 7.44. Table shows different tank locations. All dimensions in inches.



Model 120 Model 102 Model 104 Model 103

Figure 3.- Plan and rear view of model configurations tested.

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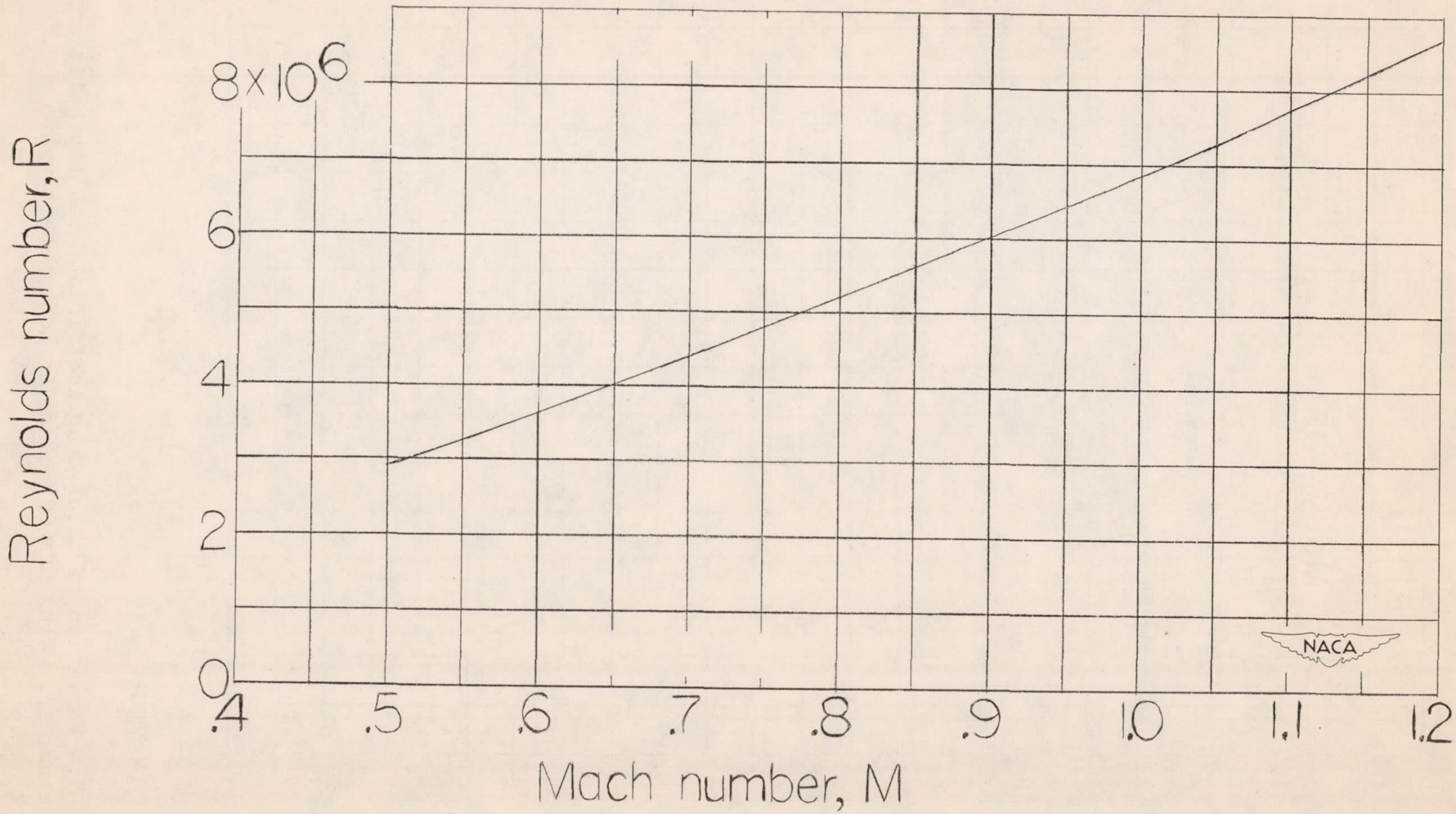
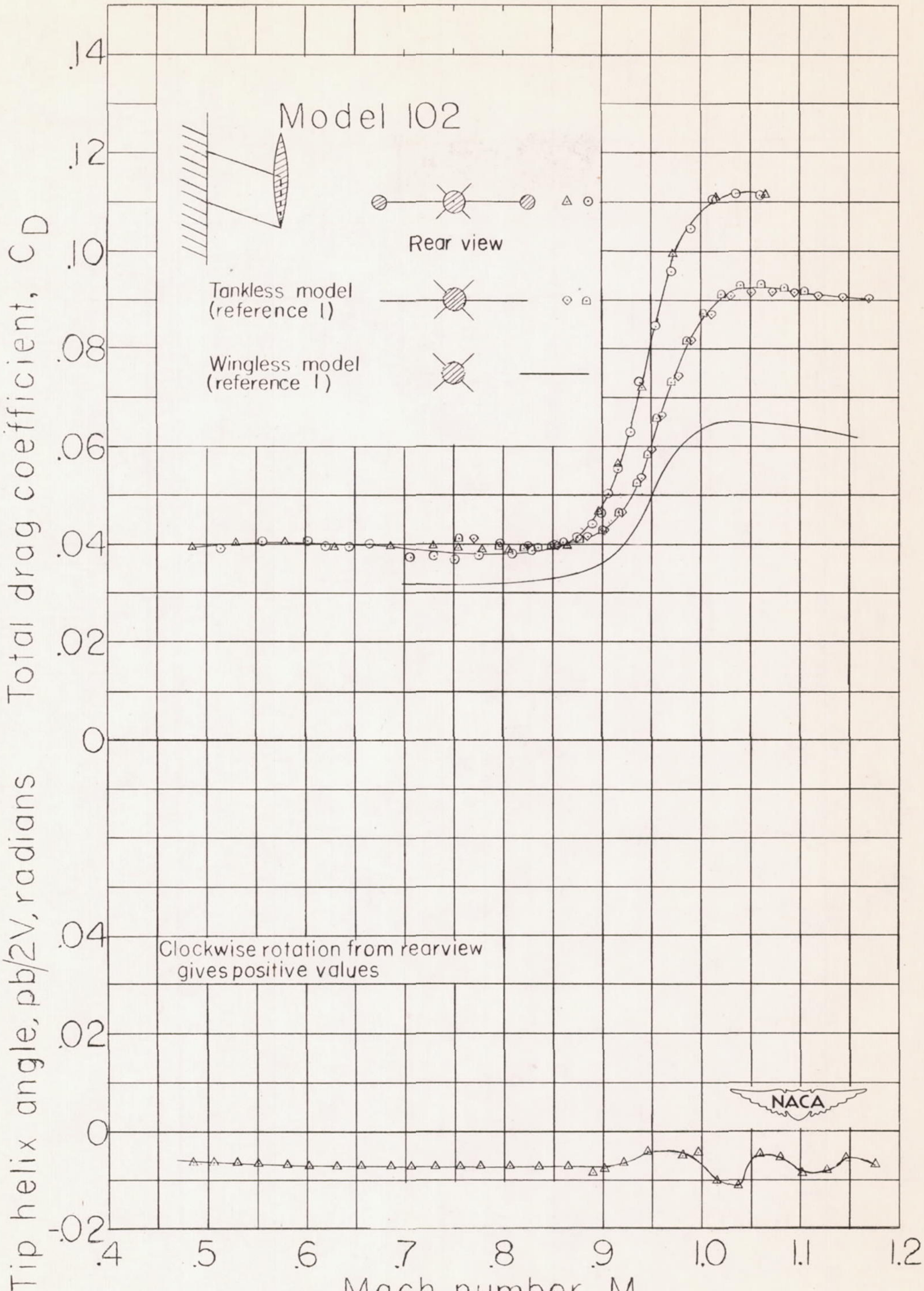
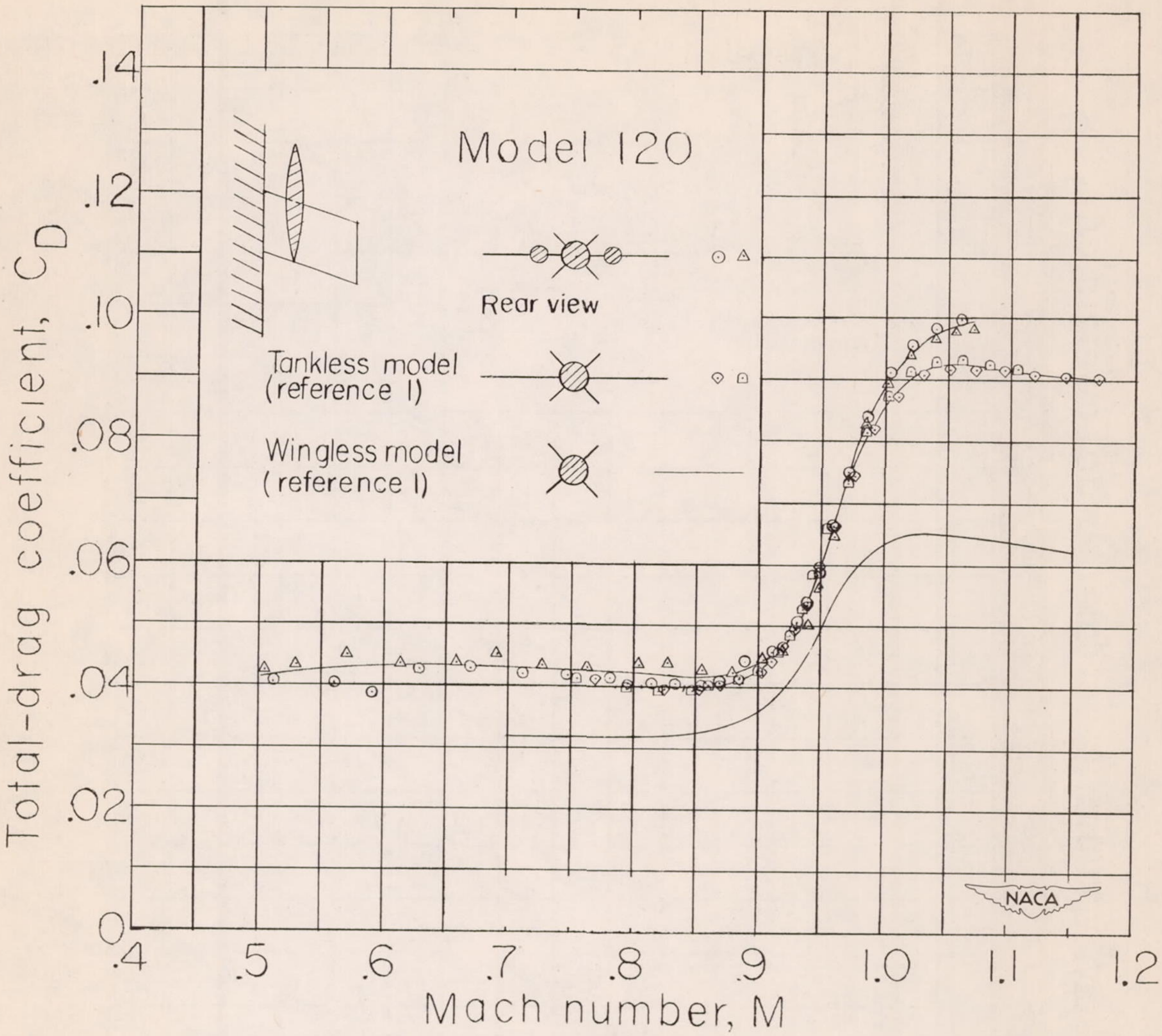


Figure 4.- Average variation of Reynolds number with Mach number for all models tested, based on wing chord, 9.647 inches.



(a) Model 102.

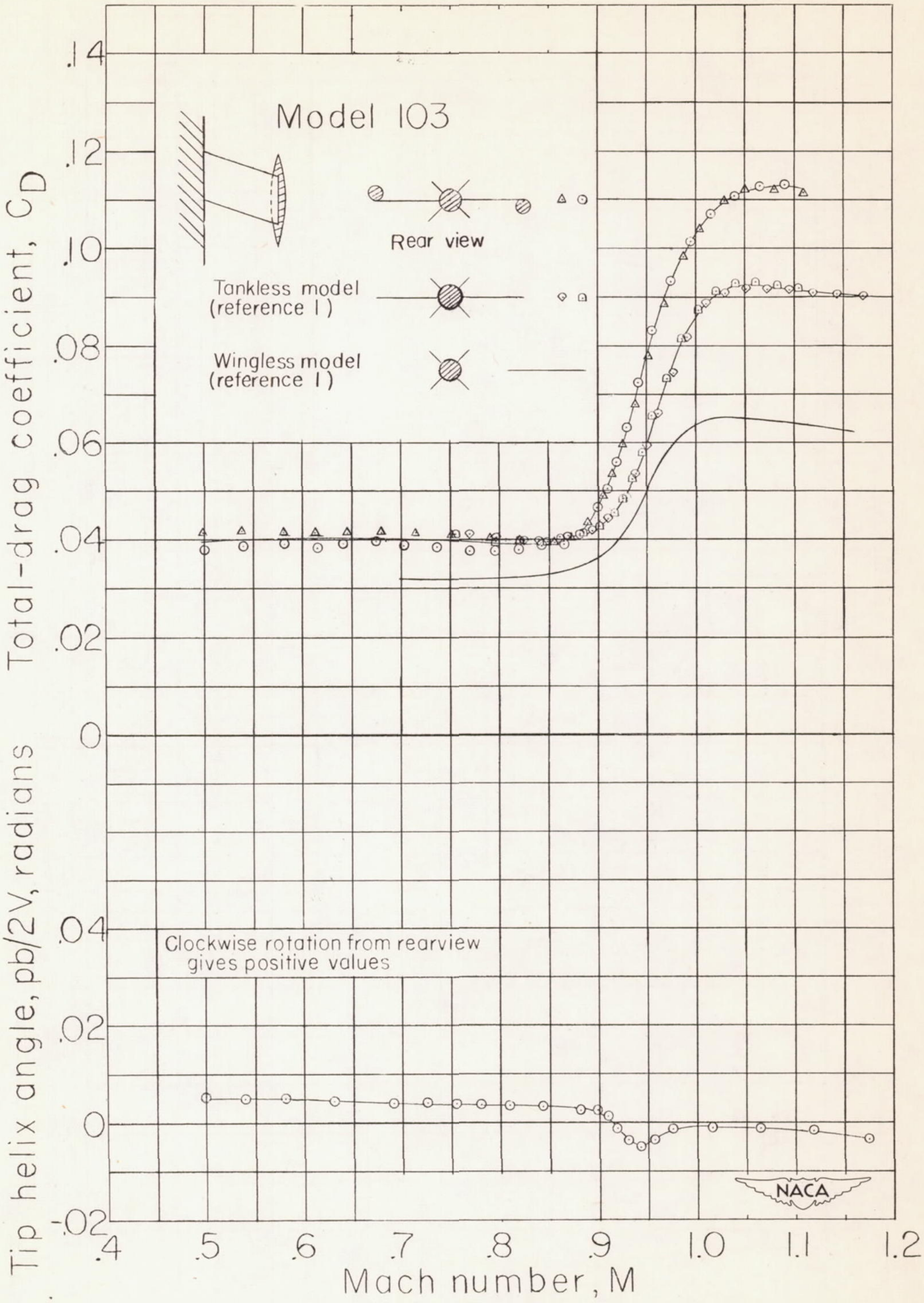
Figure 5.- Variation of total-drag coefficient and tip helix angle with Mach number. Wing of 200 square inches, aspect ratio = 2.7 and sweepback angle = 34°.



No (pb/2V) data were obtained on this model

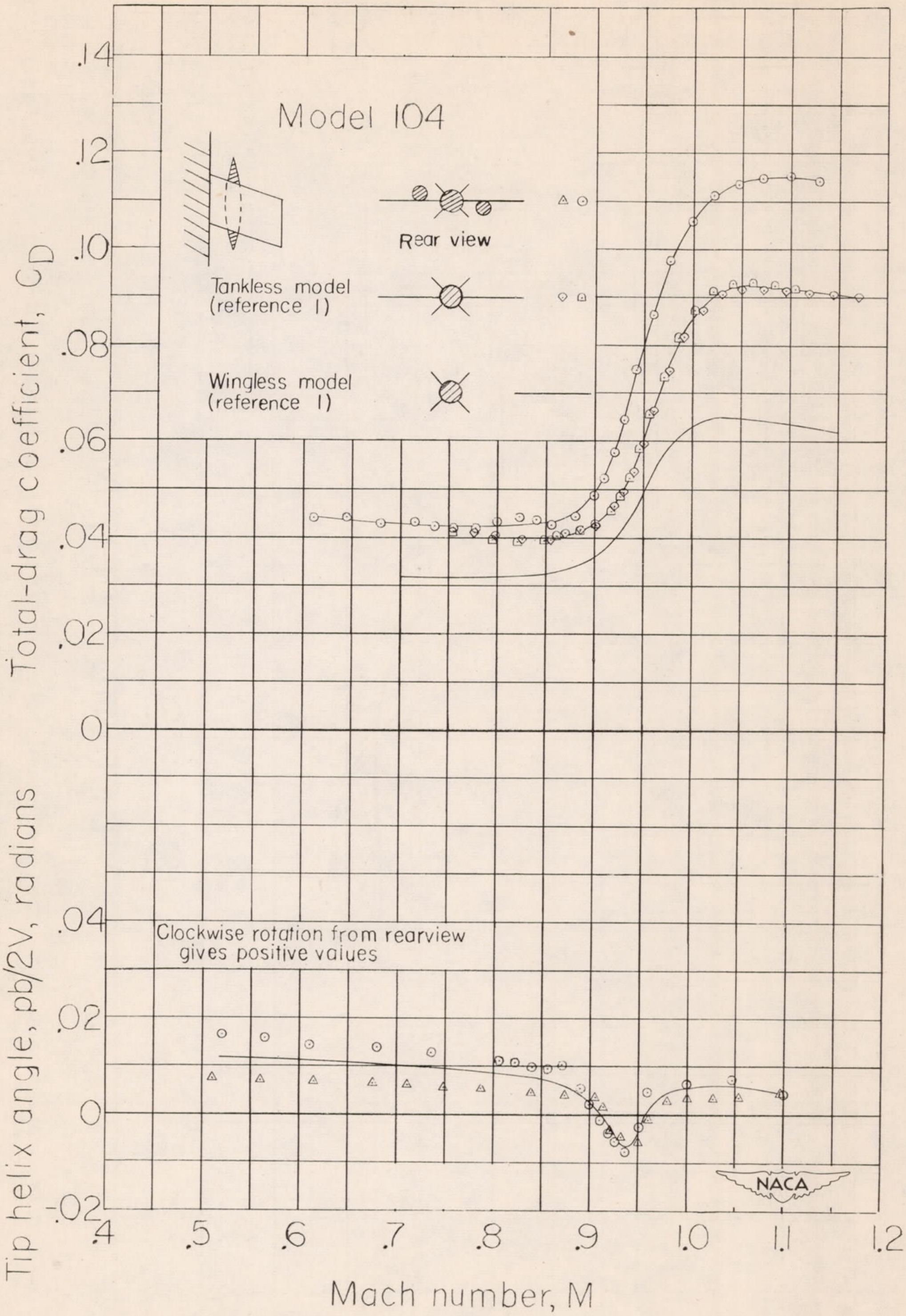
(b) Model 120.

Figure 5.- Continued.



(c) Model 103.

Figure 5.- Continued.



(d) Model 104.

Figure 5.- Concluded.

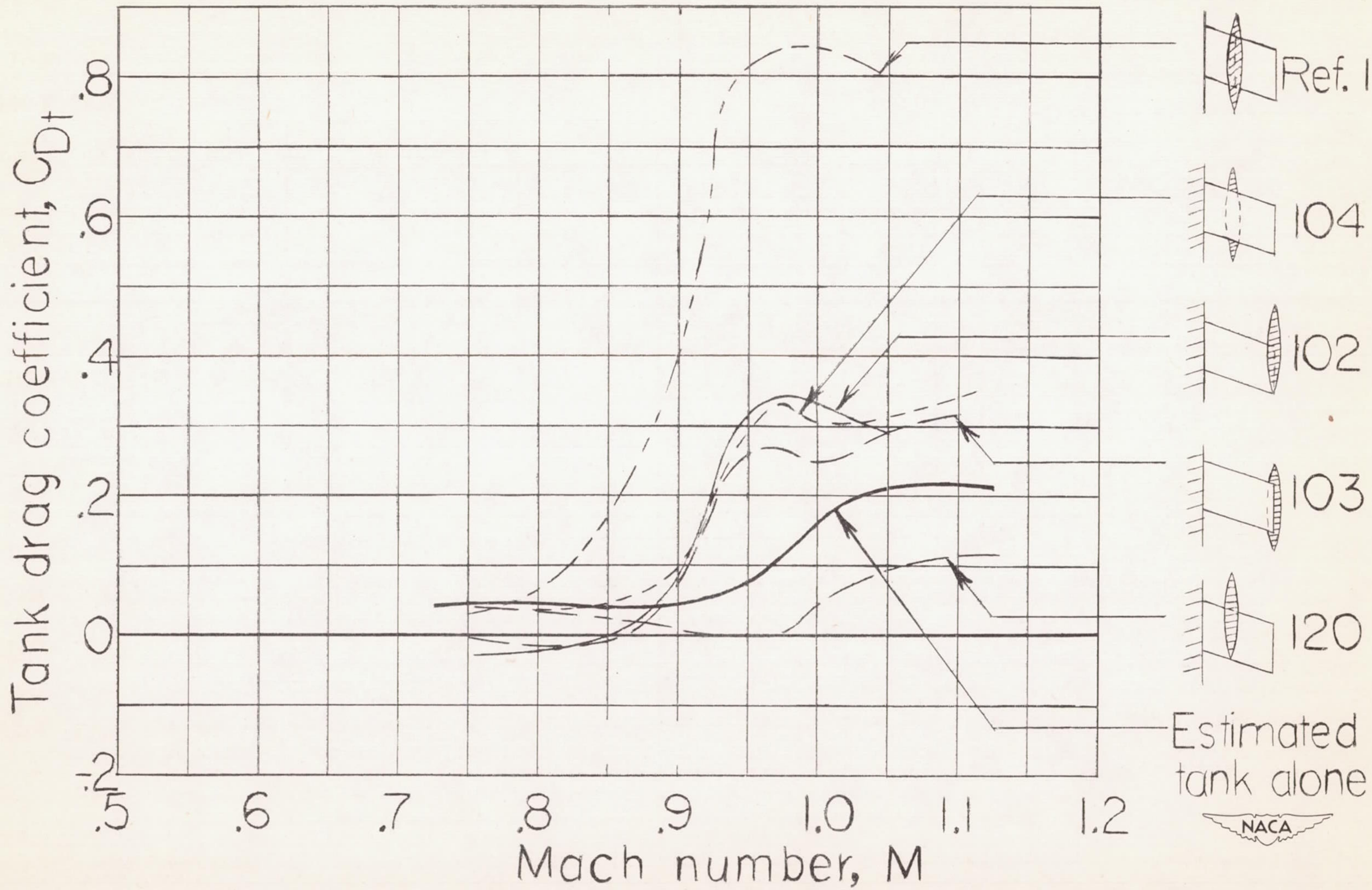


Figure 6.- Comparison of tank drag coefficients. The coefficients are based on area of two tanks equal to 13.2 square inches. Tank fineness ratio = 7.44.