NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1166

VARIATION OF HYDRODYNAMIC IMPACT LOADS WITH FLIGHT-PATH ANGLE FOR A PRISMATIC FLOAT AT 0° AND -3° TRIM AND WITH A $22\frac{1}{2}$° ANGLE OF DEAD RISE

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SUMMARY

Tests were made on a prismatic float model to determine the relationship between the vertical landing acceleration and flight-path angle for seaplanes landing in smooth water. The tests were made at both high and low forward speeds and at trims of 0° and -3°. The model had a $22\frac{1}{2}°$ angle of dead rise and a gross weight of 1100 pounds. The results of the tests indicated that, over the test range of flight-path angle, the maximum vertical landing acceleration closely approximated an exponential line for 0° trim. The runs made at -3° trim showed - with only a slight variation resulting from bow effects - that, as the flight-path angle increased, greater increases in load resulted under conditions in which the sum of the trim and flight-path angle was positive than under conditions in which this sum was negative. With the model set at -3° trim the minimum depth of immersion at the instant of maximum acceleration occurred at a flight-path angle in the region between 3° and 4°; however, greater depths were recorded which were especially noticeable at smaller flight-path angles. Observations based on the results of this test indicated possible hazards accompanying low-attitude high-speed landings.

INTRODUCTION

A series of tests have been conducted in the Langley impact basin to determine the effect of the flight-path angle upon the hydrodynamic landing loads. Tests previously reported were made at trims of 3°, 6°, 9°, and 12°. (See references 1 to 3.) The purpose of the tests described herein was to extend the investigations carried out in the tests of references 1 to 3 into the low trim range by securing data at 0° and -3° trim. Furthermore, since evidence has been presented (references 4 and 5) that suction effects may be present during landings carried out at very low trims and flight-path angles, it was desired to obtain data relevant to this phenomenon under the controlled testing conditions possible in the impact basin. The tests were made in smooth water with the model described in references 1 to 3. The results of the test made at 0° trim are representative of those for a prismatic form with an angle of dead rise of $22\frac{1}{2}^{\circ}$, whereas the test made at -3° trim furnishes results which are not representative of the prismatic form with constant dead rise, inasmuch as the initial water contact is made at the bow where the dead rise varies.

SYMBOLS

V	resultant velocity of float, feet per second
V_h	horizontal velocity component of float, feet per second
V_v	vertical velocity component of float, feet per second
g	acceleration of gravity (32.2 ft/sec^2)
F_{i_w}	hydrodynamic impact force normal to water, pounds
W	total weight of model, pounds
$n_{i_{w_{max}}}$	maximum impact load factor $\frac{F_{i_w}}{W}$
τ	float trim angle, between model base line (fig. 1) and level water, degrees
γ	flight-path angle, degrees $\left(\tan\gamma = \frac{V_v}{V_h}\right)$
y	vertical displacement of float, inches

EQUIPMENT AND INSTRUMENTATION

The impact-basin test model M-1, which has a $22\frac{1}{2}^{\circ}$ angle of dead rise, is the float described in references 1 to 3. The lines and pertinent dimensions of this model are shown in figure 1. The gross weight of the model, including the drop linkage, was 1100 pounds. The equipment and instruments used throughout the tests were the same as those described in reference 2. Impact normal accelerations were obtained from an NACA air-damped accelerometer, which had a frequency of 21 cycles per second.

TEST PROCEDURE

The model was tested with 0° yaw at trims of 0° and -3° in smooth water. The horizontal velocity for these tests ranged from approximately 45 feet per second to 100 feet per second, and the vertical velocity ranged from approximately 0.8 foot per second to 10 feet per second. The approximate range of flight-path angle determined from the combination of vertical and horizontal velocities was from 0.7° to 10°. The depth of immersion of the model was measured from the initial water contact and in a direction perpendicular to the level water surface. During the impact process a lift equal to the total weight of the model and drop linkage was exerted on the float by means of the buoyancy engine described in reference 6. All test measurements were recorded as time histories.

PRECISION

The apparatus used in the present tests yield measurements that are believed correct within the following limits:

Horizontal velocity, feet per second	±0.5
Vertical velocity, feet per second	±0.2
Vertical displacement, inches	±0.2
Acceleration, g	±0.5
Weight, pounds	±2.0

RESULTS AND DISCUSSION

The maximum load factor was derived from accelerometer records obtained for each impact. Since the buoyancy engine contributed an upward force equal to the total weight of the model, 1g was subtracted from values obtained directly from the accelerometer record in order to isolate the hydrodynamic force resulting from the impact.

Inasmuch as the maximum impact normal acceleration was shown in reference 6 to be proportional to the square of the resultant velocity, the hydrodynamic load factor was divided by V^2 to obtain this quantity independent of the velocity. The values of $n_{i_{w_{max}}}/V^2$ for float trims of 0° and -3° are plotted against the flight-path angle at the instant of water contact in figures 2 and 3, respectively.

From the data presented in figure 2 the variation of $n_{i_{w_{max}}}/V^2$ with γ for 0° trim appears to be, for most practical purposes, a simple power function over the test range. This fact is in agreement with the results of references 1 to 3, which showed the variation for a series of positive trims up to 12°. The slope of the curve for 0° trim (fig. 2) is steeper than those derived at the higher trims. This fact further substantiates the conclusions of references 2 and 7; namely, that at the low flight-path angles the predominating force effects were due to the downward deflection imparted to the water impinging upon the float bottom, whereas at the high flight-path angles the predominating forces resulted from acceleration of the virtual mass.

The results obtained from the runs made at -3° trim are not analagous to those obtained from the positive trims, since at negative trims the initial water contact occurs at the bow - a section of varying dead rise and varying effective trim. Notwithstanding this fact, the data of figure 3 indicate a trend that appears to be peculiar to the runs made at negative trim and low flight-path angles. The curve as determined by the data secured at flight-path angles above the region between 3° and 4° is for most practical purposes a straight line. The data obtained at flight-path angles below this region, however, fall to the left of the curve extrapolated in the region of low values of $n_{i_{w_{max}}}/V^2$. This phenomenon apparently indicates that the runs made at flight-path angles greater than those in the region between 3° and 4° exhibited greater increases in load as the flight-path angle increased than those made at flight-path angles below this region. This result can be explained by the presence of a reduced pressure area over a part of the float bottom at the low flight-path angles. If the effect of bow curvature is neglected, this reduced pressure phenomenon should become apparent when the algebraic sum of the trim and flight-path angle is negative; that is, when the trim is -3° the flight path angle must be less than 3°. Under this condition, although the float is immersing, its forward-velocity component is such that the float bottom tends to pull away from the water with which it is in contact. It can be noted in figure 3, however, that the change seems to occur in the flight-path range between 3° and 4°, indicating that this phenomenon makes its appearance at slightly higher flight-path angles than are necessary to make the algebraic sum of the trim and flight-path angle zero. This behavior is attributed to the convex curvature in the bow region which induces such a flow pattern to the water initially contacted by the bow that the pressures on the rear wetted part of the bottom are reduced. It is expected that the reduced-pressure phenomenon will increase in magnitude with increases in velocity and with decreases in flight-path angle and trim.

Reduced pressures at negative trim and low flight-path angle have a pronounced effect upon the depth of immersion attained at the time of maximum force. This effect can be observed by comparison of the two curves showing the variation of depth of immersion with flight-path angle at the time of maximum g for 0° and -3° trim. (See fig. 4.) The trend of the 0° trim curve conforms with data obtained in references 1 to 3 for the higher trims, since the depth of immersion at the time of maximum g increases continuously with increasing flight-path angles; whereas, the curve representing the -3° condition shows that the minimum depth was attained at a flight-path angle in the region between 3° and 4°. Observations based on the magnitude of the depth of immersions obtained with both negative trims and positive trims at the very low flight-path angles show the negative-trim immersions to be abnormally large. The increase in depth of immersion with decreases in flight-path angles below 4° evidently results from the reduced vertical force in this range; therefore, in order to dissipate the vertical momentum, a greater depth of immersion is necessary to allow the virtual mass, dynamic lift, and buoyancy forces to build up sufficiently and to act throughout a longer period of time.

The data secured at the negative trim indicate some possible hazards involved in high-speed low-attitude landings. One such hazardous condition would result from the high speeds associated with landings made at low trims and low flight-path angles. Such a condition would result in exceedingly high bow loads because of the large dynamic pressures built up due to the speed. In addition to constituting a severe structural condition, a high bow load, when coupled with the reduced pressures occurring further aft, could provide a large stalling moment. Under these conditions the airplane would be thrown into a stalled attitude with a consequent loss of the pilot's ability to control it. An additional hazard associated with negative-trim landings is indicated by the curve of figure 4, which shows abnormally great depths of immersion resulting from this type of landing. The higher drag forces that would be developed under such circumstances could produce large and perhaps dangerous longitudinal accelerations. This drag force would tend to alleviate the foregoing stalling characteristics. During these tests, however, no instrumentation was available to measure the water pressures, drag loads, and pitching moments; therefore, the determination of the predominating forces affecting the stability and structural components of the airplane throughout the immersion would require further investigations.

CONCLUDING REMARKS

Tests of a prismatic float were made in the Langley impact basin to determine the relationship between the hydrodynamic landing loads and flight-path angles for seaplanes landing in smooth water.

The results of the tests made for constant model weight and at model trim of 0° indicated that the variation of maximum impact normal acceleration with flight-path angle showed very good agreement with an exponential line.

The runs made at -3° trim showed - with only a slight variation resulting from bow effects - that, as the flight-path angle increased, greater increases in load resulted under conditions in which the sum of the trim and flight-path angle was positive than under conditions in which this sum was negative. With the model set at -3° trim, the minimum depth of immersion at the instant of maximum acceleration occurred at a flight-path angle in the region between 3° and 4°; whereas much greater depths were recorded at smaller flight-path angles.

The results indicated that the low-attitude, high-speed landings might constitute a marked hazard. During these tests, however, no instrumentation was available to measure the water pressures, drag loads, and pitching moments; therefore, the determination of the predominating forces affecting the stability and structural components of the airplane throughout the immersion would require further investigations.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., January 31, 1947

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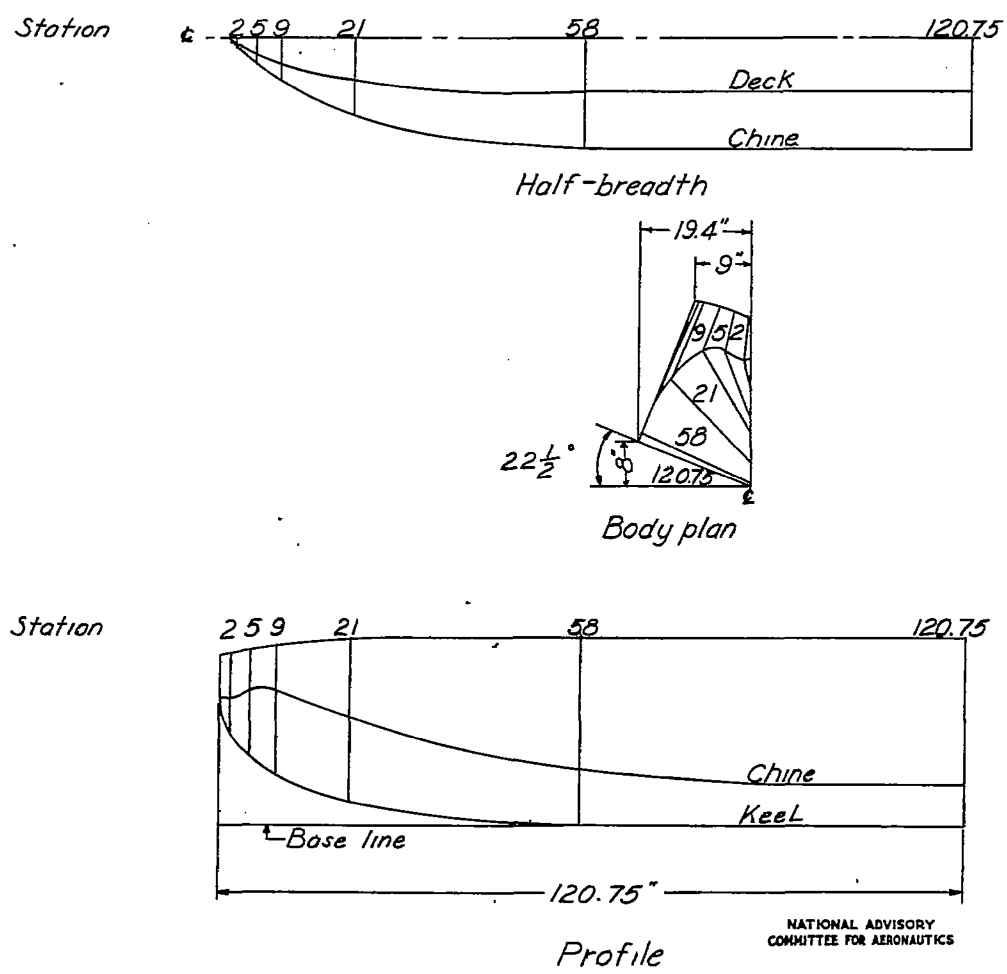

Figure 1.- Lines of float model M-1 tested in Langley impact basin.

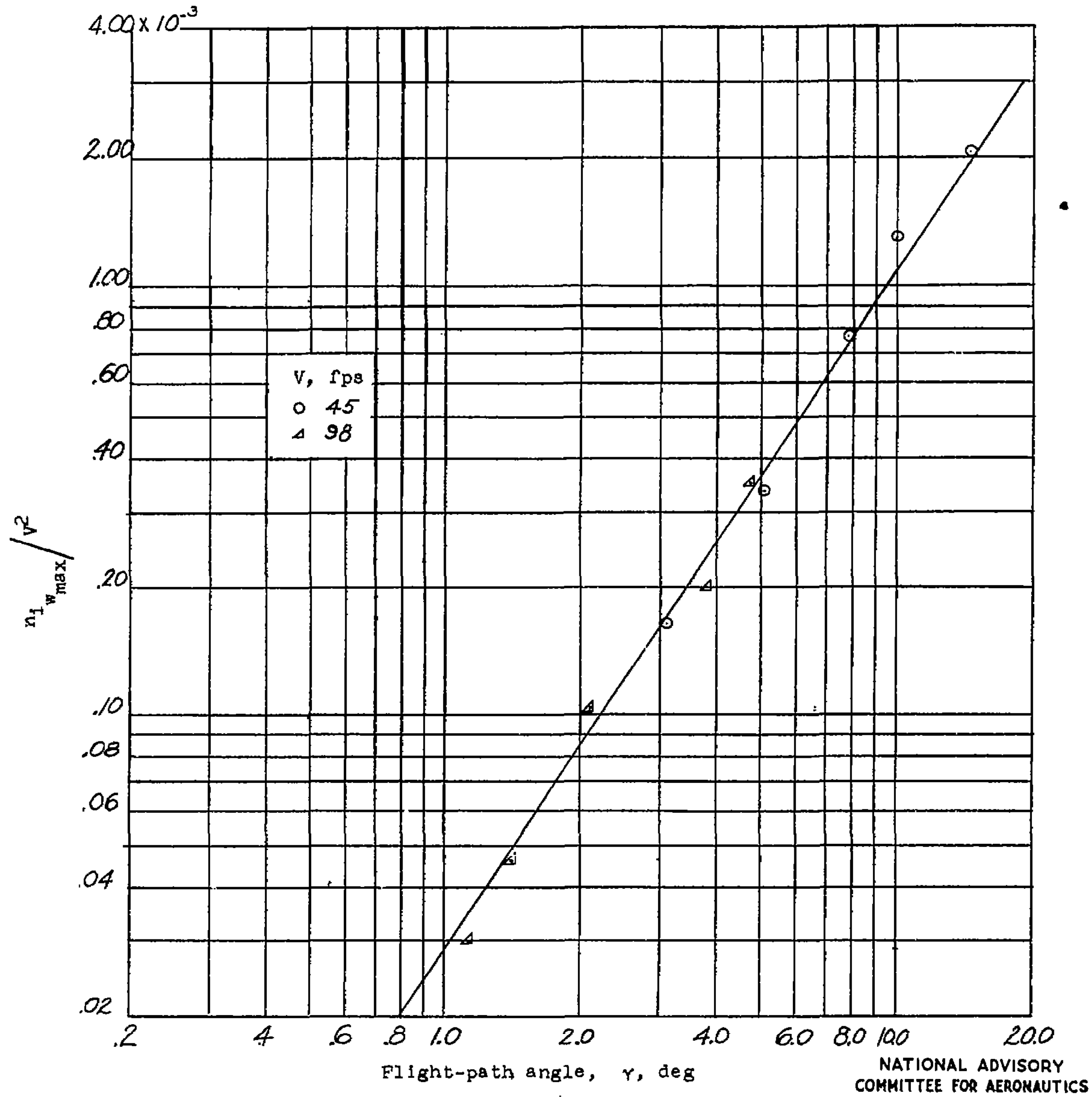

Figure 2.- Variation of parameter $n_{i_{w_{max}}}/V^2$ with flight-path angle. $\tau = 0^\circ$; W = 1100 pounds.

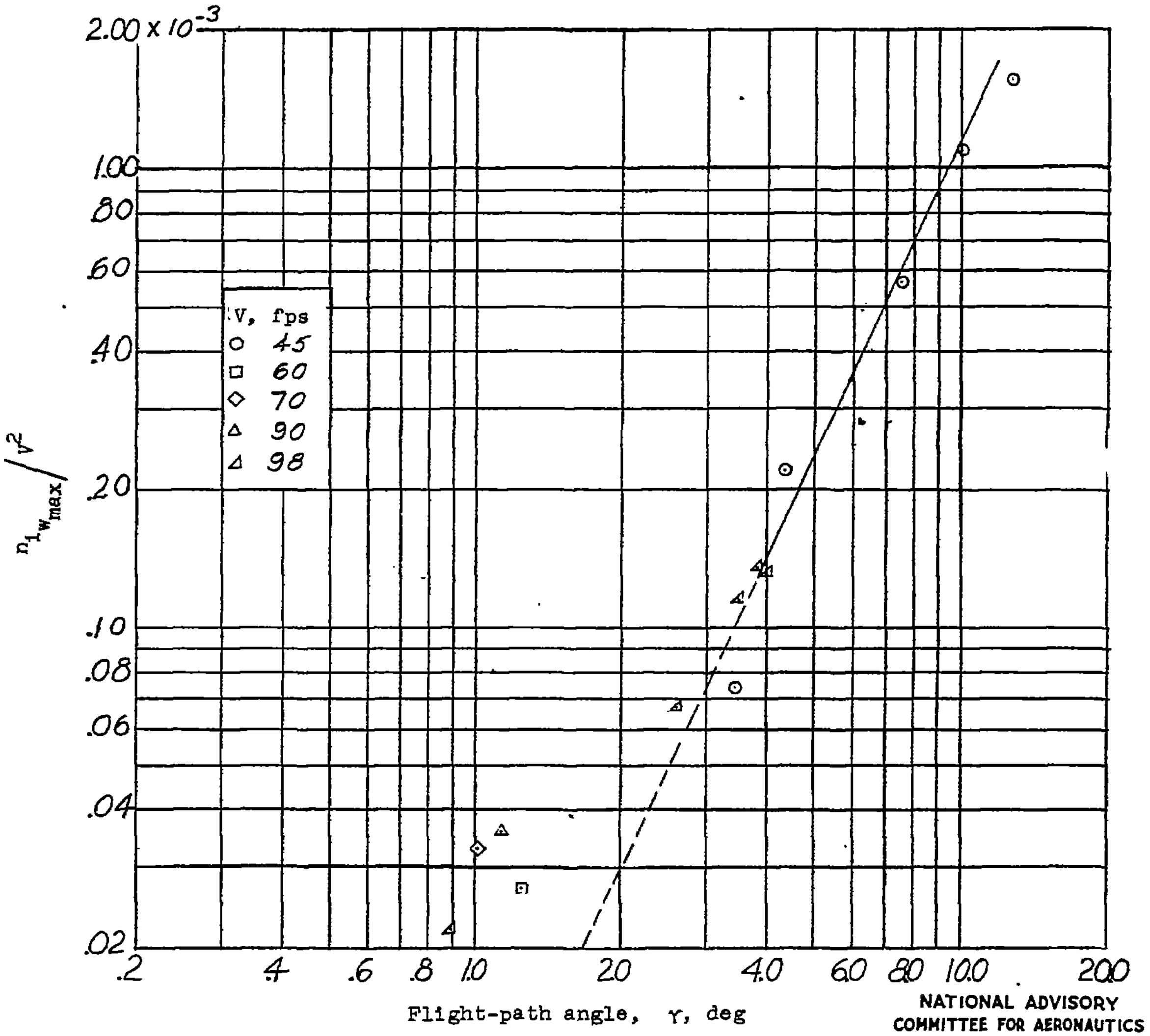

Figure 3.- Variation of parameter $n_{1_{w_{max}}}/V^2$ with flight-path angle. $\tau = -3^{\circ}$; W = 1100 pounds.

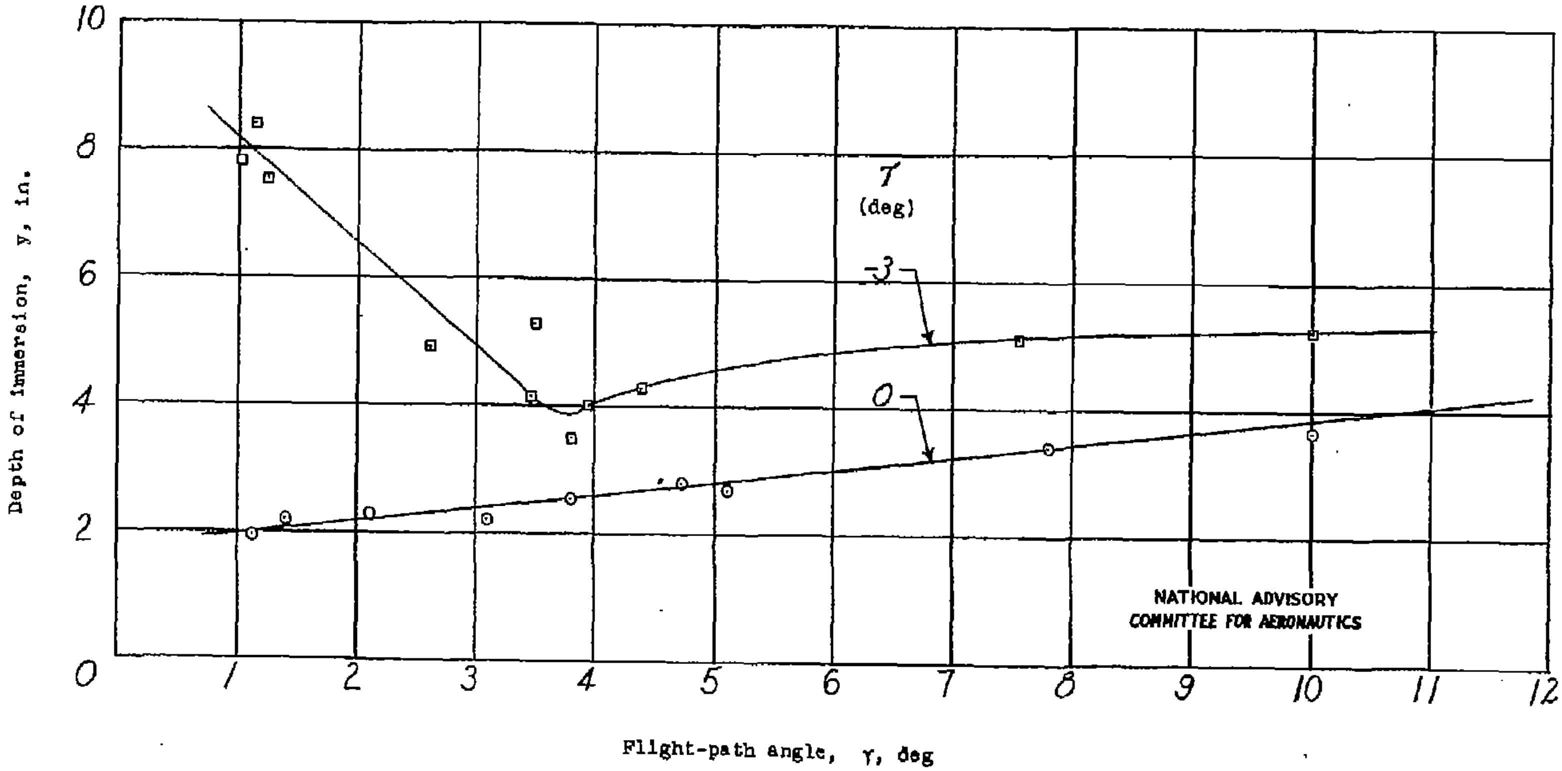

Figure 4.- Variation of depth of immersion at time of maximum acceleration with flight-path angle. W = 1100 pounds.