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Istribution Eglin Dield British ais Comm. RESTRICTED Hoy. a.a.d. Ballistic research Laboratory Brit Ord. Board Mary mrs Ryan 1 mr Dettmian's office. Della Participation OF SHALL REPORT CORRECTIONS OF ELEMENTS OF BOMBING TABLES FOR EFFECTS OF HEIGHT OF TARGET BX E. J. MCSHANE RETURN TO TECHNICAL DIVISION FIRING RECORD UNIT 111 1 2 1943 REPORT NO. 374 ABERDEEN PROVING GROUND JULY 2, 1943 ABERDEEN, MD.

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BALLISTIC RESEARCH LABORATORY REPORT NO. 374

EJMcS/lcr Aberdeen Proving Ground, Md. 2 July 1943

CORRECTIONS OF ELEMENTS OF BOMBING TABLES FOR EFFECTS OF HEIGHT OF TARGET

Abstract

Two possible procedures for computing the effect of height of target on range or trail are discussed. The simpler method is shown to yield corrections differing very little from those obtained by the theoretically sounder but more complicated method. It is, therefore, recommended for use.

INTRODUCTION

1. In conversations with Dr. H. E. Heinecke, and in correspondence 0.0. 063.2/1541 APG 353.42/1205, it has been brought out that many air fields at which bombardiers are trained have altitudes between 3000 and 6000 feet above sea level. Since bombing tables are prepared for targets at sea level, a systematic error is introduced by the use of such tables at the fields having high altitudes. It was, therefore, suggested that the Ballistic Research Laboratory prepare tables permitting correction for height of target above sea level.

The present report contains a discussion of the theoretical basis for the computation of such correction tables. The computations have already been completed, under the direction of Mr. E. S. Martin. The principal conclusion is that there is no point in adopting any procedure of greater theoretical refinement than the pure-drag solution presented in section I.

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I. The Pure-Dreg Solution

If the air produced no effect on the motion of the bomb except through drag, and the drag coefficient were accurately known, it would be very easy to produce such tables.

Suppose that a bomb is launched from horizontal flight at an altitude Y feet above sea level and speed v_0 feet per second. Suppose also that the drag function is G(v) and the reciprocal ballistic coefficient is Y, and the air z feet above sea level has the ballistic standard density

$$p = p e^{-az}$$

$$(p_0 = .0751 \text{ lb/ft}^3, a = .0003158 \text{ ft}^{-1}).$$

Choose axes with origin at the point of release, x-axis horizontal in the direction of flight, and y-axis vertically downward. The trajectory is then the solution of the equations:

(1.1)
$$\ddot{x} = -\gamma e^{-a(Y-y)}G(v)\dot{x},$$

$$\ddot{\mathbf{y}} = \mathbf{g} - \gamma \mathbf{e}^{-\mathbf{a}(\mathbf{Y}-\mathbf{y})} \mathbf{G}(\mathbf{v}) \dot{\mathbf{y}}$$

with initial conditions

(1.2)
$$\mathbf{x}(0) = \mathbf{y}(0) = \mathbf{\dot{y}}(0) = 0, \ \mathbf{\dot{x}}(0) = \mathbf{v}_0$$
.

(As usual, the factor ρ_0 is incorporated in G, and v denotes the air speed of the bomb.)

Now consider a bomb aimed at a target Y_{02} feet above sea level, launched from an airplane in horizontal flight Y feet above the target (and, therefore, $Y + Y_{00}$ feet above sea level) at speed v_0 feet per second. Axes are chosen as before, with origin at point of release, x-axis in line of flight and y-axis vertically down. The point with coordinates (x,y) is now at altitude $Y + Y_{00} - y$ feet above sea level, so air density

$$-a(Y + Y_{0} - y)$$
 times standard density ε sea level.

The differential equations of the trajectory are:

(1.3) $\dot{x} = -\gamma e^{-e(\gamma + \gamma_{to} - \gamma)}G(\gamma) \dot{x}$,

$$\dot{\mathbf{y}} = \mathbf{g} - \gamma \mathbf{e}^{-\mathbf{g}(\mathbf{Y} + \mathbf{Y}_{\omega} - \mathbf{y})} \mathbf{G}(\mathbf{v}) \dot{\mathbf{y}} ,$$

with initial conditions (1.2). But equations (1.3) can be written in the form

(1.4)
$$\dot{x} = -(\gamma e^{-aY\omega}) e^{-a(Y-y)}G(v) \dot{x},$$

 $\dot{y} = g - (\gamma e^{-aY\omega}) e^{-a(Y-y)}G(v) \dot{y}.$

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These are equations (1.1) with only the change that the constant γ is replaced by the constant

Hence, if the drag function $G(\mathbf{v})$ is accurately known and the air produces no effect except drag on the bomb, the trajectory of a bomb with reciprocal ballistic coefficient γ launched Y feet above a target $Y_{\mathbf{W}}$ feet above sea level will be exactly like the trajectory of a bomb with reciprocal ballistic coefficient

launched Y feet above sea level, and with the same speed.

II. <u>CORRECTIONS BASED ON PURE-DRAG SOLUTION</u> The effect of replacing y by

is to increase the range of the bomb and decrease its time of fall. However, it would be quite inconvenient for a bombardier to have to interpolate for two different small corrections, one to trail and one to time of fall or DS, and set both corrections on the bomb sight. In the absence of cross-wind, a correction to trail alone can be given which will produce the correct point of impact. Let RP₁ be the track of the airplane; in



the absence of cross-wind, this passes over the target M to obtain a hit. Let P_1 be the point vertically below the airplane at the instant of impact. For a hit, MP₁ must equal the trail λ_1 of the bomb. Let R be the point vertically below the airplane at the instant of release. Then RP₁ is the travel of the airplane during the time of flight T₁ of the bomb. If v_g is the ground speed of the airplane,

$$RP_{1} = v_{g}T_{1}, \quad so$$
$$RM = v_{g}T_{1} - \lambda_{1}.$$

If an incorrect time of flight T_2 is used instead of T_1 , impact will occur when the airplane is vertically above P_2 , where

$$RP_2 = v_g T_2 \cdot Hence$$
$$P_1 P_2 = R(T_2 - T_1) \cdot$$

A hit will still be obtained if $\lambda_2 = MP_2$ is set in as the trail instead of the correct value MP₁. For then

$$RM = v_{\sigma}T_{2} - \lambda_{2} .$$

To express it more simply, in still air it is immaterial whether the correct trail and time of flight are used, provided only that $\mathbf{v}_{g}\mathbf{T} - \lambda$ is equal to the true value of the range X = RM of the bomb. The effect of raising the target above sea level is to increase the range by an amount Δ X. In still air, a hit will be obtained if $\mathbf{v}_{g}\mathbf{T} - \lambda$ is also increased by an amount Δ X. This can be done correctly, but inconveniently, byreducing both T and λ to their new value. More conveniently, it can be done by decreasing λ by the amount Δ X. This simplified process leads to no error in still air.

It remains to investigate the error caused by this simplification when there is a wind. Let M be the vector representing the wind at release. The situation, like many others involving winds, can be rather easily visualized by choosing axes fixed with respect to the air at release. In these axes there is no wind, but the ground is sliding by the axis-system with velocity -W. The situation is thus mathematically the same as in bombing a uniformly moving target in still air. The Norden bomb sight takes correct account of such target motion or wind (apart from an error called the "range component of cross trail" which is insignificant except for light bombs in high cross-winds), provided that the correct time of flight is used. The signal for release is given when the relative position of airplane and target is such that T seconds later (T = time of flight of bomb) the target will have reached the point of impact. If, however, the time of flight is falsely assumed to be T + ΔT , release will take place at such an instant that T + ΔT seconds later the target will have reached the point of impact. But the bomb reaches this point T seconds after release, at which time the target has a vector displacement $(-\underline{W})(-\Delta T) = \underline{W} \Delta T$ from the point of impact. The effect of height of target is to produce a negative ΔT . So the bomb will strike upwind of the target, at a distance equal to the distance the release wind travels in time $|\Delta T|$.

The magnitude of this error may be seen from the following brief table in which Y is the altitude above target in feet, Ym is 5000 feet and ΔT is the change in time of flight of a 100-lb. Bomb, Practice, M38A2.

	ΔΤ	:	
Y	v, mi	150	400
10,000		15	20
20,000		37	42
30,000		57	63

From this it follows that the target error, in feet, due to a 50 mi/hr wind at release is as follows:

Y V	150	400
10,000	11	15
20,000	27	31
30,000	42	46

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or in mils is

Y	V	150	400
10,000		1.1	1.5
20,000		1.4	1.6
30,000		1.4	1.5

It would not seem practical to reduce this small error by further complicating the bombardier's task.

III. ERRORS INHERENT IN THE PURE-DRAG SOLUTION

The pure-drag solution in section I is based on two false assumptions, namely that the drag is accurately known and that no aerodynamic forces other than the drag produce appreciable effects. The former can be further subdivided into the two errors that the drag function is know for standard temperature and that the temperature structure is the same between I_{00} and $Y + Y_{10}$ as between 0 and Y. This last may be disposed of at once. This last may be disposed of at once. The effect of temperature may indeed be appreciable, but it would be absurd to consider it in a small correction term while its effect on the data in the main table is ignored. At some future date, temperature corrections to trail and time of flight may be made. But then these will be corrections to the tabulated trail and time of flight, and it is hardly to be anticipated that the small correction for height of target will ever need to be itself corrected for temperature.

A somewhat similar statement applies to the error in the drag function. At present all bombing tables are obtained with the help of ballistic tables, based on the Gåvre drag function, and there are many indications that this is not even a fair approximation to the true drag function for any bomb in present use. Consequently, all corrections based on the Gâvre drag function are subject to suspicion. But this is far less important than the fact that uncertainty also prevails in the bombing table itself. When a better drag function is determined, the outstanding use of it will be to improve extrapolation in bombing tables, and only after that to improve correction terms. In any case, it is out of the question to try to correct for erroneous drag function in the height-of-target correction, since as yet, no adequately trustworthy drag function has been determined.

The other false assumption in section I is that no aerodynamic force except lift is worth considering. The lift force also produces very perceptible effects. This will now be discussed.

IV. EFFECT OF STEADY LIFE ON HEIGHT-OF-TARGET CORRECTION

It has been known for some years, as a result of range bombings at the Aberdeen Proving Ground, that the drag is not the only aerodynamic force which appreciably affects the motion of the bomb. There is also a force perpendicular to the direction of motion of the bomb. This has been investigated in some detail in Ballistic Research Laboratory Report No. 325, "The Plane Yawing of Bombs Launched from Horizontal Suspension". The effect is produced almost entirely by a slowly varying component of force in the vertical plane containing the trajectory and perpendicular to the trajectory, and with magnitude

$$M \lambda (p/p_0) \cos \theta$$

where Θ is the angle between the horizontal and the tangent to the trajectory, λ is a constant depending on the bomb and with the dimensions of an acceleration and M is the mass of the bomb.

The coefficient λ can be evaluated from the results of range bombing at the 2000 foot level.* The result at present has not as great accuracy as might be desired, but it is hoped that improved equipment will help in this respect. Never-the-less, the values given in the report cited are at least of the right order of magnitude. It appears that the value of λ for the M38A2 practice bomb is greater than for any other, and is about .011g.

The equations of motion, when the steady lift is included, take the form

(4.1)
$$\begin{aligned} \mathbf{x} &= -\Upsilon e^{-\mathbf{a}(\Upsilon - \mathbf{y})} G(\mathbf{v}) \cdot \mathbf{x} + \chi e^{-\mathbf{a}(\Upsilon - \mathbf{y})} \mathbf{x}' \mathbf{u}^2 \\ &\vdots \\ \mathbf{y} &= \mathbf{g} - \Upsilon e^{-\mathbf{a}(\Upsilon - \mathbf{y})} G(\mathbf{v}) \cdot \mathbf{y} - \lambda e^{-\mathbf{a}(\Upsilon - \mathbf{y})} \mathbf{x}' \mathbf{y}^2. \end{aligned}$$

As before, consider a bomb launched from a height Y + Ye above a target whose altitude is Ye. The differential equations of the trajectory become

(4.2)
$$\dot{\mathbf{x}} = -\gamma e^{-\mathbf{a}(\underline{Y}_{\mathbf{W}} + \underline{Y} - \mathbf{y})} G(\mathbf{v})\dot{\mathbf{x}} + \lambda e^{-\mathbf{a}(\underline{Y}_{\mathbf{W}} + \underline{Y} - \mathbf{y})} \dot{\mathbf{x}} \mathbf{y}/u^{2}$$
,
 $\dot{\mathbf{y}} = \mathbf{g} - \gamma e^{-\mathbf{a}(\underline{Y}_{\mathbf{W}} + \underline{Y} - \mathbf{y})} G(\mathbf{v})\dot{\mathbf{y}} - \lambda e^{-\mathbf{a}(\underline{Y}_{\mathbf{W}} + \underline{Y} - \mathbf{y})} \dot{\mathbf{x}}^{2}/u^{2}$.

These can be written in the form

(4.3)
$$\ddot{\mathbf{x}} = -(\gamma e^{-aY\omega}) e^{-a(Y-y)}G(\mathbf{v})\dot{\mathbf{x}} + (\lambda e^{-aY\omega})e^{-a(Y-y)}\dot{\mathbf{x}}\dot{\mathbf{y}}/u^2$$
,
 $\ddot{\mathbf{y}} = g - (\gamma e^{-aY\omega})e^{-a(Y-y)}G(\mathbf{v})\dot{\mathbf{y}} - (\lambda e^{-aY\omega})e^{-a(Y-y)}\dot{\mathbf{x}}^2/u^2$,

These are equations (4.1) with the change that Y, λ are replaced by

Ballistic Research Laboratory Report No. 337, "Separation of Lift and Drag Effects on Bomb Trajectories by Analysis of Range Bombing Data."

respectively.

The effects of the steady lift are too large to ignore, but are small enough to be accurately treated as differential corrections to the pure-drag trajectory. A table of the effect of lift on range and on time of flight has been computed by the method set forth in Ballistic Research Laboratory Report No. 327, and will be found at the end of this present report. This table is not extensive enough for all purposes, and since it will later be extended, it has not been put in final form. However, it is adequate for the present discussion. The argument log C_S is the logarithm to base 10 of the "summital ballistic coefficient", which is $1/\gamma e^{-aY}$ when the launching is at Y feet above sea level. Hence

(4.4) $\log C_s = aY \log_{10} e - \log_{10} Y$ = .000013716Y - $\log_{10} Y$,

if Y is in feet.

Now, if the drag function were accurately known, a correct procedure for determining the effect of a height of target Y_{00} would be the following. First, using the reciprocal ballistic coefficient Y_X determined by the range, find log C_g by (4.4), and find the effect of lift $\lambda = .01$ g on range. Multiply this by $\lambda / .01$ g (which for the 100-lb. W38A2 practice bomb is 1.1) and subtract from the observed range. This gives the range corrected for lift. From the Ballistic Reduction Tables find the corresponding γ . Properly, this should be repeated using this new γ in place of γ_X , but in fact, the change in lift effect due to the correction to γ is negligibly small. Next multiply the corrected γ by

and from the Ballistic Reduction Tables find the range corresponding to this new γ . From the table of lift effects, find the effect on range corresponding to reciprocal ballistic coefficient

or

(4.5)
$$\log C_{s} = .000013716(Y + Y_{W}) - \log_{10} Y$$

Multiply this by

$$(\lambda e^{-aY\omega}) / .01g$$
.

and add to the range found from the Ballistic Reduction Tables. The difference between this sum and the range for target at sea level is the range correction sought, and as seen in section II can be used as the correction to trail.

If the drag function were accurately known, the process of correcting γ_{\pm} for lift effect described in the beginning of the preceding paragraph would lead (except for experimental error) to the same value of γ as would the exactly analogous process of correcting γ_{\pm} for lift effect. Since the Gâvre drag function is not correct for bombs, there will still be a discrepancy between the ballistic coefficients for time and range, even after correcting for lift. As previously stated, nothing can be done about this at present, and so the ballistic coefficient for time will be ignored.

The process just described, although accurate, is rather cumbersome to use. Its form will, therefore, be modified. To begin with, it is convenient to replace the range X by the range lag

$$B = vacuum range - X.$$

Since the velocity at launching and the height above target are unchanged in making the correction, the vacuum range is unaltered by elevating the target. So the increase in range is equal to the decrease in range lag. Also, since speed and altitude are fixed, B depends only on γ . The B corresponding to a given γ will be denoted by $B(\gamma)$, and the γ corresponding to a given B will be denoted by γ (B). Also, B' (γ) will mean dB/d γ and $\gamma'(B)$ will mean d γ/dB , and B''(γ) will mean d² B/d γ^2 .

Let B_0 be the range lag for the bomb launched at the given speed at a height Y feet above a target which is at sea level, and let l_0 be the additional range due to lift effect. Then the range lag which drag alone would produce would be $B_0 + l_0$, and the reciprocal ballistic coefficient (for range) as corrected for lift is

(4.6)
$$\gamma(\mathbf{B}_0 + \mathbf{l}_0),$$
 $\alpha = e^{-\Upsilon \omega},$

Consider now the trajectory of a bomb dropped from Y feet above a target at level Y_{40} . As has been shown, the range lag due to drag is that which corresponds to reciprocal ballistic coefficient $\propto \gamma (B_0 + I_0)$, that is $B(\propto \gamma (B_0 + I_0))$. The new lift effect is found by computing the lift effect $1(\alpha \gamma)$ corresponding to the new reciprocal ballistic coefficient $\alpha \gamma (B_0 + I_0)$ and multiplying by α ; it will be denoted by $\alpha I(\alpha, \gamma)$. The range lag is then

$$B(\alpha Y (B_{0} + 1_{0})) - \alpha 1(\alpha Y).$$

The pure-drag method expounded in section I would lead to the new range lag

$$B(\alpha \vee (B_0)).$$

Hence, the error in the pure-drag method due to ignoring the lift effect

is

(4.7)
$$\mathbf{\xi} = \mathbf{B}(\chi \Upsilon (\mathbf{B}_0)) - \mathbf{B}(\chi \Upsilon (\mathbf{B}_0 + \mathbf{1}_0)) + \alpha \mathbf{1}(\alpha \Upsilon)$$
$$= \mathbf{B}(\chi \Upsilon (\mathbf{B}_0)) - \mathbf{B}(\chi \Upsilon (\mathbf{B}_0 + \mathbf{1}_0)) + \alpha \mathbf{1}_0 + \alpha \mathbf{1}(\alpha \Upsilon) - \mathbf{1}_0].$$

The first two terms represent the difference of the values of the function $B(\chi\gamma(B_0 + z))$ at z = 0 and at $z = 1_0$. By the theorem of mean value, this is -1_0 times the derivative of the function at some point z between 0 and 1_0 . But

$$\frac{\mathrm{d}}{\mathrm{d}z} B(\alpha \Upsilon(B_0 + z)) = B^{\dagger}(\Upsilon(B_0 z)) \cdot \alpha \Upsilon^{\dagger}(B_0 + z).$$

Hence

(4.8)
$$\varepsilon = \pi l_0 \left\{ 1 - B'(\alpha Y(B_0 + \overline{z})) Y'(B_0 + \overline{z}) \right\} + \alpha \left[1(\alpha Y) - l_0 \right].$$

By the theorem of mean value,

$$B^{\dagger}(\alpha \Upsilon (B_{o} + \overline{z})) = B^{\dagger}(\Upsilon (B_{o} + \overline{z})) + (\alpha -1) \Upsilon (B_{o} + \overline{z})B^{\dagger}(\alpha \Upsilon (B_{o} + \overline{z}))$$

where $\overline{\alpha}$ is between \times and 1. On substituting this in (4.8) and recalling that

$$\gamma (B_0 + \bar{z}) = 1/B(\gamma (B_0 + \bar{z}))$$
,

it is found that

(4.9)
$$\varepsilon = \alpha(1 - \alpha) \mathbf{1}_0 Y (\mathbf{B}_0 + \mathbf{z}) \mathbf{B}^{\dagger} (\overline{\alpha} Y (\mathbf{B}_0 + \mathbf{z})) / \mathbf{B}^{\dagger} (Y (\mathbf{B}_0 + \mathbf{z}))$$

$$+ \times 1(\alpha Y) - 1_0$$
.

Inspection of the tables shows that B' is positive and B'' negative, while $l(\sigma, \gamma)$ is greater than l_0 . Hence, the two terms in (4.9) have opposite signs, and the error is numerically less than the numerically larger of the two terms on the right. In order to discuss a fairly extreme case, it will be supposed that $Y_{00} = 5000$ feet, whence

$$\alpha = .8539$$
 .

Also, elevation by 5,000 feet increases C_s by .06818. Inspection of the table of lift effects shows that for lift coefficient .01g a change of log C_s by .06818 does not affect the range correction by more than about 2 feet. Hence, for $\lambda = .011$ g (which is the value corresponding to the 100-1b. M38A2 practice bomb, and is apparently not exceeded for any G.P. or A.P. bomb) the term $\alpha [1(\alpha r) - 1_0]$ remains under 2 feet. If it is numerically the greater of the two terms on the right of (4.9), ε is negligible; otherwise, the second term merely serves to reduce the effect of the first term.

Both B' and B'' decrease numerically as Y increases, so

(4.10)
$$|B^{\mu}(\bar{\gamma}(B_{0} + \bar{z})/B^{\mu}(\gamma(B_{0} + \bar{z}))|$$

= $|B^{\mu}(\alpha \gamma(B_{0} + \bar{z}))/B^{\mu}(\gamma(B_{0} + \bar{z}))|$.

Both l_0 and the right member of (4.10) increase with speed of launching, so they will be estimated at 480 miles per hour. The argument Y in the Ballistic Reduction Tables is tabulated at intervals of .1, and it is quite adequate to consider that B' (Y) is ten times the mean first difference, and B''(Y) is the hundred times the central second difference. Computation shows that - Y B''/B' does not exceed .462 for $Y \leq$ 1.3, and does not exceed .528 for $Y \leq$ 1.9. For $\lambda/.01g = 1.1$ the lift effect on range does not exceed 105 feet for any entry in the table. So for $Y \leq$ 1.3 the value of the first term in (4.9) can never exceed 6.05 feet. The same estimate will continue valid past Y = 1.9 because of the decrease of lift effect on range with increasing Y. Moreover, this 6.05 feet is still to be diminished by the small term

$$\alpha [1(\alpha \gamma) - 1_0].$$

At lower altitudes and speeds, the error is still smaller. For example, at altitude 20,000 feet above target and speed 320 mi/hr. true, it is less than 2.5 feet for all bombs having $\gamma \leq 1.0$.

It is, therefore, clear that it would be pointless to complicate the computation of the table of corrections for height of target by considering lift effect separately from drag effect. Accordingly, the tables of height-of-target corrections already computed for the 100-1b. M38A2 practice bomb were prepared by the pure-drag method of section 1, and this method will also be quite accurate enough for use in preparing height-of-target correction tables for any bomb.

E. J. McShani

E. J. Mc Shane

EFFECTS OF STEADY LIFT WITH > = .01g

TRUE AIR SPEED 160 mi/hr

		Ra	nge Effec	t, Feet	5341	Time o	f Flight	Effect,	seconds
Y Lo	g C _s	0.0	0.4	0.8	1.2	0.0	0.4	8.0	1.2
2000		15	16	16	16	.042	.041	.041	.041
4000		23	24	25	25	.049	.048	.048	.048
6000		29	30	31	31	.052	.051	.051	.050
8000		33	35	36	37	.053	.052	.051	.050
10000		36	39	40	40	.052	.052	.050	.050
12000		39	42	44	44	.051	.050	.049	.049
14000		41	45	47	47	.049	.048	.048	.040
16000		43	37	38	39	.048	.047	.040	.041
18000		44	48	50	51	.045	.045	.044	.04)
20000		44	49	51	52	.044	.043	.045	047
22000		44	49	52	23	.041	030	030	039
24000		44	50	52	22	.027	.039	037	037
26000		43	50)2 50	24 51	.037	036	036	.035
28000		43	20	52	51	033	034	.034	.034
30000		41	47	52	53	032	.032	.032	.032
32000		20	40	51	53	030	.030	.030	.030
34000		29	41	50	52	.028	.029	.029	.029
30000		36	1.6	50	51	.027	.027	.028	.028
30000		35	1.1.	19	50	.025	.026	.026	.026
40000		33	43	48	49	.024	.024	.025	.025
11000		11	42	46	48		.023	.024	.023
16000			41	45	47		.022	.023	.022
18000			40	44	46		.021	.022	.021
50000			38	43	45		.020	.021	.020
52000			37	42	44 .	C. Stan.	.019	.020	.019
54000			35	40	43	1	.017	.019	.018
56000				39	41			.017	.017
58000				38	40	actes of the		.010	.010
60000				37	39			.010	.015
62000				35	38	B BLE		.015	01/
64000				34	37			.014	013
66000					35				.013
68000					24				.012
70000					22				.012
72000					24	1 States			
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EFFECTS OF STEADY LIFT WITH > = .01g

÷

TRUE AIR SPHED 320 mi/hr

1		Rar	nge Effec	t, Feet	1225	Time of	f Flight	Effect.	seconds
Y	Log C _s	0.0	0.4	0.8	1.2	0.0	0.4	0.8	1.2
2000		23	26	26	27	.051	.050	.050	.0/9
4000		33	36	38	38	.063	.063	.062	.061
6000		40	44	46	47	.071	.069	.069	.067
8000		45	50	53	54	,075	.073	.071	.070
10000		49	55	58	59	.077	.074	.072	.071
12000		52	59	62	64	.076	.074	.073	.071
14000	and the second	55	62	66	67	.075	.073	.071	.071
16000		56	65	68	70	.074	.072	.070	.069
18000		57	66	70	72	.071	.070	.069	.067
20000		60	68	72	74	.069	.068	.067	.066
22000		58	68	73	75	.066	.066	.065	.064
24000		58	69	74	76	.063	.064	.062	.06]
26000		58	69	74	77	.060	.062	.060	.059
28000		57	69	74	76	.057	.059	.058	,057
30000		55	68	74	76	.054	.057	.055	.055
32000	2-12-11-21-22	54	68	74	76	.051	.054	.054	.052
34000		53	67	73	75	.047	.052	.051	.051
36000		51	65	72	74	.045	.050	.049	.048
38000		49	64	71	73	.042	.048	.047	.046
40000		47	63	70	73	.040	.045	.044	.044
42000		46	61	68	71	.038	.043	.042	.042
44000			60	67	70		.041	.040	.040
46000			58	65	69		.038	.038	.039
48000			57	64	67		.036	.036	.037
50000			54	63	00		.034	.034	.035
52000			53	61	64		.032	.033	.034
54000	- Start		51	60	03		.031	.031	.032
50000				28 54	60			.030	.031
60000				50	60			.028	.029
60000				22	20			.027	.028
62000				24	21			.020	.020
64000)T	22			.023	.020
68000	Ser and				52				.024
70000					50				022
72000	100				10				020
12000	and the second				40				.020
	2ª in								

EFFECTS OF STEADY LIFT WITH > = .01g

TRUE AIR SPEED 480 mi/hr

YL	og C _s	0.0	0.4	0.8	1.2	0.0	0.4	0.8	1.2
2000		32	36	38	38	.055	.053	.052	052
4000		42	48	52	53	.072	.069	.067	.066
6000		49	58	61	63	.082	.079	.076	.074
8000		54	64	69	71	.087	.083	.081	.079
10000		58	69	75	77	.090	.086	.084	.082
12000		61	73	79	83	.090	.087	.085	.084
14000		63	76	84	87	.090	.087	.085	.084
16000		65	78	86	89	.089	.087	.084	.083
18000		66	80	88	92	.087	.086	.083	.082
20000		66	81	89	94	.084	.084	.082	.080
22000		66	82	90	94	.081	.082	.080	.078
24000		66	82	91	95	.078	.079	.078	.076
26000		66	82	92	95	.075	.077	.076	.074
28000		65	82	92	95	.072	.074	.075	.072
30000		64	18	91	95	.068	.071	.073	.070
32000		62	80	90	94	.065	.069	.070	.068
34000		60	79	89	93	.062	.066	.067	.065
30000		29	78	88	92	.059	.063	.064	.063
10000		21	11	81	91	.057	.001	.001	.061
40000		22	15	07	90	.054	.050	.039	.009
42000		22	14	04 ¢2	00	.051	.055	.050	.050
16000			70	80	95		.053	.052	.052
18000			68	70	83		0/0	.050	050
50000			66	77	82		047	0/8	0/8
52000			61	75	80		04/	017	045
51,000			62	73	78		0/2	047	044
56000				71	76		• Cate	0/3	0/2
58000				69	75			012	.0/7
60000				67	73			.041	.038
62000				66	71			.039	.037
64000				1000	69				.035
66000					68	1 Section			.033
68000					65				.032
70000					60				.028