AD NUMBER
AD000741
CLASSIFICATION CHANGES
TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Distribution authorized to U.S. Gov't. agencies and their contractors; Specific Authority; 16 OCT 2000. Other requests shall be referred to DTIC-BC, 8725 John J. Kingman Rd., Ft. Belvoir, VA 22060-6218.
AUTHORITY
OSD/WHS case no. 11-M-1003, ltr dtd 31 Mar 2011; OSD/WHS case no. 11-M-1003, ltr dtd 31 Mar 2011

AD-741

CONFIDENTIAL

11-M-1003 R-1

FOR USE OF G-E EMPLOYEES ONLY

GENERAL ELECTRIC

APPARATUS DEPARTMENT

TECHNICAL INFORMATION SERIES

CONFIDENTIAL
SECURITY INFORMATION

AUTHOR	SUBJECT CLASSIFICATION	NO. / DATE
F.V. Johnson	Sights	TR-52A0112 DATE 12-30-52

TITLE

LIMITS OF OPERATION OF K-19 BOMBING MODE

ABSTRACT

Approximate expressions are derived for the maximum bomb release range and the separation from impact point as functions of speed and lead angle. The limits of the present K-19 bombing mode are given.

G.E. CLASS	REPRODUCIBLE COPY FILED AT	NO. PAGES
4	Data Bureau Bldg. #4	9
GOV. CLASS. Confidential		

CONCLUSIONS

For some anticipated bombing requirements of fighter airplanes the present K-19 bombing mode is marginal or inadequate because of the limitation to lead angles visible over the airplane nose.

By cutting out this rectangle and folding on the center line, the above information can be fitted into a standard card file.

For list of contents—drawings, photos, etc. and for distribution see next page (AO-147-A).

INFORMATION PREPARED FOR Aeronautic and Ordnance Division

TESTS MADE BY

COUNTERSIGNED Charles F. Green Advanced Development

DIVISIONS A & OS LOCATION Schenectady, New York

CONFIDENTIAL
SECURITY INFORMATION

AO-147 (9-50)

GENERAL ELECTRIC COMPANY
TECHNICAL INFORMATION SERIES
NO. TR-52A0112

CONFIDENTIAL
SECURITY INFORMATION

TABLE OF CONTENTS

CONFIDENTIAL
SECURITY INFORMATION

GENERAL ELECTRIC COMPANY
TECHNICAL INFORMATION SERIES
CONTENTS PAGE

CONTENTS OF REPORT

NO. PAGES TEXT 9

NO. CHARTS

DRAWING NOS.

PHOTO NOS.

DISTRIBUTION

AO-147-A (9-50)

LIMITS OF OPERATION OF K-19 BOMBING MODE

(1) Maximum Bombing Range from Fighter Airplanes

The trajectory followed by a bomb after release from an airplane is determined by the direction of the flight path at the moment of release, but not by the curvature of the path. The maximum range at which a bomb can be released therefore does not depend directly on whether the path of the airplane is one of more than 1 g (toss bombing) or less than 1 g (dive bombing). It is shown in Appendix A that the bombing range depends on the dive angle, the speed of the airplane, and the lead angle between flight path and line of sight at the point of release. For low dive angles the range, neglecting retardation, may be approximated closely by

$$D = .068\ V^2\ L$$

where

D is range in yards

V is speed in knots

L is lead angle in radians between flight path and line of sight to target.

Thus the maximum bombing range for a given airplane depends almost entirely on the lead angle permitted. If a bombing system requires tracking the target optically, L may be limited by view over the nose to 10° or 12°. On the other hand if the system does not require tracking to the point of release so that the lead angle at release may reach 20° or 25°, the range may be doubled, but with an almost certain reduction in angular accuracy.

Maximum ranges for various speeds based on a 12° lead angle are tabulated below.

TABLE I

V Knots	D Yards
300	1280
400	2280
500	3570
600	5130
700	7000

(2) Maximum Clearance from Impact Point

The clearance which the airplane can develop between itself and the bomb at the instant of impact depends on the number of g's at which it can pull away from the zero-lift path of the bomb, and on the time of flight between release and impact. The time of flight is in turn a function of only the lead angle and the speed at time of release. Thus the clearance is not primarily a function of the path of the airplane before the release point. Actually a finite time is required for an airplane flying a path of 1 g or less to achieve, say, a 4 g path after release, but this time is small compared to the bomb time of fall, which may be 10 to 20 seconds at high speed and maximum range. It is shown in Appendix B that neglecting this, for low dive angles the clearance may be approximated by

$$C = \left(\frac{V\ L}{3.93}\right)^2 g_s$$

where

- C is clearance from impact point in yards
- V is speed in knots
- g_s is number of g's total acceleration after release
- L is lead angle in radians between flight path and line of sight to target.

Thus the clearance also increases as the lead angle at release increases. For values of L above 15° the above expression will begin to have serious errors.

Maximum clearances based on a lead angle of 12° and a total loading of 4 g after release are tabulated below.

TABLE II

V Knots	C Yards
300	1010
400	1800
500	2810
600	4050
700	5500

(3) Shape of K-19 Bombing Path

The bombing mode established for the first K-19 sights requires tracking the target for a time of 5 seconds before release. It is thus able to introduce a lead correction to compensate in part for the effects of wind and motion of the target. Since the target must be on the line of sight at the time of release, this also limits the lead angle to that which may be seen over the nose of the airplane.

The path produced in the bombing mode is tentatively described as toss bombing, since the net curvature of the airplane path is upward. At the start of the bomb run the line of sight is closely constrained to the armament datum line of the airplane, and the pilot flies nearly directly toward the target. During the run the line of sight is given a depression rate, and the pilot must nose the airplane upward to keep on the target. For the last two seconds the rate of the line of sight is so adjusted that the airplane flies a straight path aimed above the target, reaching the required lead angle at the point of release. At no time is the path one of downward curvature, as characterizes dive bombing.

Since the net curvature of path is upward, the bomb run can be started from any elevation from which the target is visible. If the initial elevation is low, the bomb run may terminate in a climb. The climb angle will necessarily be limited to less than the maximum lead angle that can be seen over the nose.

(4) Limits of Operation of K-19 in Bombing Mode

It was shown in sections (1) and (2) that a maximum range for tossing the bomb and a maximum clearance are fixed when the speed of airplane and the maximum lead angle are known. These do not depend on the manner in which the bomb sight operates to set up the lead angle, except that some paths are barred to a dive bomb system because they require the airplane to fly out of the ground. Since the K-19 does not produce a dive bomb path, any problems within the limits of sections (1) and (2) are theoretically within its capabilities. The value of 12° for the maximum lead angle as used in computing the tables is near the limit for most fighters; however a low g maneuver permits the pilot the best opportunity to see large lead angles.

In order to simplify the instrumentation of the K-19 bombing mode, certain additional limits have been set for the sights as presently being built. These are as follows:

(a) The calibration is optimized for low dive angles, in the order of 0° to 30°. For higher angles the accuracy deteriorates. The calibration might with equal ease be optimized for a steeper dive, or a manual input of estimated dive angle could be provided. Automatic input of dive angle to cover a wide range of values would increase the complexity considerably.

(b) The bomb program unit is now calibrated to permit release at ranges down to 1200 feet at 300 knots or 1800 feet at 500 knots, and up to 3500 feet at 300 knots or 5600 feet at

500 knots. Increasing the span of maximum to minimum range while providing continuously variable inputs is difficult with the circuitry used. The range of values provided was felt to fit best the expected use of the sight with conventional weapons against tactical targets. For weapons requiring longer release ranges, the entire calibration could be moved up toward the maximum range limits derived in section (1), or a series of discreet calibration points covering the entire possible range of operation could be provided. Neither of these would require additional complexity of equipment.

(5) Prediction for Wind and Target Motion

Optical tracking of the target up to the point of bomb release necessarily limits the maximum lead angle, and therefore the range and clearance. It does, however, eliminate the errors which result from flying blind during the critical part of the bomb run, and it provides rate information on which to base corrections for wind and target motion.

It is pointed out in TR-52A0108 that the condition of infinite sensitivity reached by the K-19 at the release point is the condition in which the sight sets up a constant bearing, or collision course. This course is the one required to compensate for the effects of wind and target motion.

This correction builds up from an initial value of essentially zero. It may be described conversely as a transient error having an initial value equal to the final correction, which decays to approach zero. It can be shown that if the sensitivity is infinite, the transient dies out with the fourth power of range. Since the actual sensitivity is less than infinity up to the end of the program, the transient dies out at a lower rate than this. The problem is extremely complex and has not been completely investigated. It is clear, however, that the transient will decay more completely for short range problems than for long, unless the length of the bomb program is also increased at long ranges.

October 23, 1952 F. V. Johnson

APPENDIX A

From equation (18) of TR-52A0108 we have

$$\frac{D_o}{V_A} = .214\ V_A \ \sin \Lambda_o$$

Let D_o be replaced by D for simplicity;

sin Λ_o be replaced by L, which is a satisfactory approximation for L up to 15^o; and V_A be replaced by .563V, where V is speed in knots.

Then

$$D = .068V^2\ L$$

APPENDIX B

Let t be the time from release to impact. Since the bomb will travel nearly the same distance as the airplane in this time, using the nomenclature of TR-52A0108

$$D_o = V_A\ t$$

From equation (17)

$$D_o = V_A\ t = \frac{2\ V_A^2 \ \sin \Lambda_o \ \cos \Delta_o}{g\ \cos^2 \ \mathcal{E}_o}$$

$$t = \frac{2\ V_A \ \sin \Lambda_o \ \cos \Delta_o}{g\ \cos^2 \ \mathcal{E}_o}$$

Since the bomb follows a path of zero lift, and the airplane one of g_s g lift, they will pull apart with this acceleration. The direction of this acceleration actually changes as the airplane path changes direction. However for the times of flight involved in this analysis, it is found that nearly the entire acceleration can be taken as producing clearance. Thus

$$C = \frac{g\, g_s\, t^2}{2}$$

$$C = \frac{2\, V_A^2\, g_s \sin^2 \Lambda_o}{g} \quad \frac{\cos^2 \Delta_o}{\cos^4 \epsilon_o}$$

If we substitute conditions for horizontal flight at release,

$$\sin \Lambda_o = L$$
$$V_A = .563\ V$$
$$g = 10.7$$
$$\Delta_o = 0^\circ$$
$$\epsilon_o = 12^\circ$$

we obtain

$$C = \left(\frac{V\ L}{3.93}\right)^2 g_s$$

AD-

741

CONFIDENTIAL

UNCLASSIFIED

SECRET

DEPARTMENT OF DEFENSE
WASHINGTON HEADQUARTERS SERVICES
1155 DEFENSE PENTAGON
WASHINGTON, DC 20301-1155

MAR 3 1 2011

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
(ATTN: WILLIAM B. BUSH)
8725 JOHN J. KINGMAN ROAD, STE 0944
FT. BELVOIR, VA 22060-6218

SUBJECT: OSD MDR Cases 11-M-1002, -1003, -1005, -1007, -1008, and -1009

We have reviewed the attached documents and have no objection to declassification in full. The information you requested is provided in the table below:

OSD Case Number 11-M-	Current Controlling Agency	Current Controlling Official	Current Distribution Control Statement	Current Overall Classification Level	Current Downgrading Instructions	Current Declass. Instructions
1002	WHS	OSD Records Official	A Release Unlimited	C	N/A	N/A
1003	WHS	OSD Records Official	A Release Unlimited	C	N/A	N/A
1005	WHS	OSD Records Official	A Release Unlimited	C	N/A	N/A
1007	WHS	OSD Records Official	A Release Unlimited	C	N/A	N/A
1008	WHS	OSD Records Official	A Release Unlimited	S	N/A	N/A
1009	WHS	OSD Records Official	A Release Unlimited	S	N/A	N/A

If you have any questions, contact me by phone at 703-696-2197 or by e-mail at storer.robert@whs.mil or robert.storer@whs.smil.mil.

Robert Storer

Robert Storer
Chief, Records and Declassification Division

Enclosures:
1. DTIC request
3. Six documents

SECRET

UNCLASSIFIED [redacted]