AD'703145

BRL

REPORT NO. 248

EXPERIMENTAL DATA FORMING THE BASIS FOR

THE BOMBING TABLES BT-100-B-3 FOR

THE BOMB, PRACTICE, 100-LB., M38A2

by

E. S. Martin
Ellen Boyle

March 1942

U.S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

EXPERIMENTAL DATA FORMING THE BASIS FOR THE BOMBING TABLES
BT-100-B-3
FOR THE
BOMB, PRACTICE, 100-LB., M38A2

Abstract

This report records the essential data on which the bombing tables
BT-100-B-3 are based. A short description of the bomb is given as well as
the mechanical constants of the bombs used. The methods used in range
bombing and the methods of obtaining essential data are described. The
methods used to determine the ballistic coefficients as well as the methods
used in constructing the bombing tables are also given. Graphs showing
the results of range bombing and graphs showing the fitted $C : Y$ relations
are included.

1.   Purpose of Report

The purpose of this report is to record the essential
details of the experimental work, the computing methods and
the experimental data upon which the bombing tables BT-100-B-3
for the Bomb, Practice, 100-lb., M38A2 are based.

II.   Description of Bombs

The Bombs, Practice, 100-lb., M38A2 used in range bomb-
ing for the bombing tables BT-100-B-3 were made in accordance
with Ordnance Department Drawing Number No. 82-0-23 dated
December 24, 1937and revised April 29, 1938.

III.   Preparation of Bombs

The following page gives an outline drawing of the Bomb,
Practice, 100-lb., M38A2 with weights and measurements which
were prescribed for range bombing and obtained from observations.

The bomb is made of relatively thin sheet metal and is
stored and shipped to the place of issue empty to keep handling

PHYSICAL CHARACTERISTICS
BOMB, PRACTICE, 100-LB., M38A2
DRG. NO. 82-0-23   REV. 4-29-38
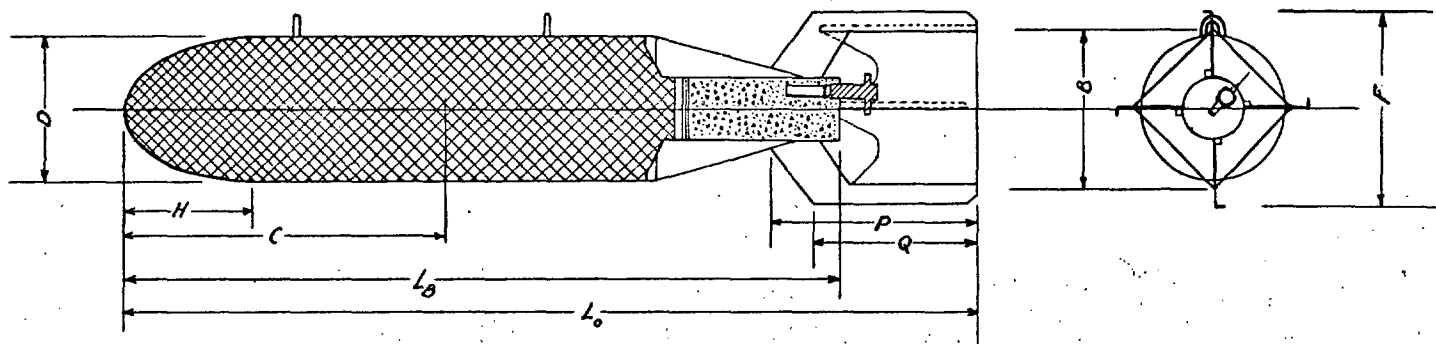
PRINCIPAL DIMENSIONS

DIMENSION	INCHES	CALIBERS	REMARKS
D	8.0	1.00	AS GIVEN ON DRAWING
B	8.5	1.06	AS GIVEN ON DRAWING
F	10.75	1.34	AS GIVEN ON DRAWING
L_o	47.5	5.94	AS GIVEN ON DRAWING
L_B	40.6	5.08	AS GIVEN ON DRAWING
H	7.1	0.89	AS GIVEN ON DRAWING
P	11.4	1.42	AS GIVEN ON DRAWING
Q	9.1	1.14	AS GIVEN ON DRAWING
C	18.14 $\sigma=0.242$	2.27	MEAN FROM RANGE BOMBING
C	18.16 ±.25		OF BODY ASSEMBLY AS PRESCRIBED FOR RANGE BOMBING WITH TOLERANCE

COMPONENTS AND WEIGHTS

	COMPONENTS	WEIGHT (LB.)	REMARKS
BODY ASSEMBLY	BODY	15.7	AS GIVEN ON DRAWING INCLUDING SUSPENSION LUGS AND FINS
	SPOTTING CHARGE ASSEMBLY	1.25	LESS SPOTTING CHARGE
	SPOTTING CHARGE	3.0	BLACK POWDER (SODIUM NITRATE)
	FILLER	80	SAND - AS GIVEN ON DRAWING
COMPLETE AS DROPPED		100	AS GIVEN ON DRAWING
COMPLETE AS DROPPED		99.3 $\sigma=0.85$	MEAN FROM RANGE BOMBING

EXPECTED MAXIMUM VARIATION IN WEIGHT AS LOADED = ±2.57

RATIO: WEIGHT OF BURSTING CHARGE : WEIGHT AS DROPPED = —

EXPERIMENTAL DESIGNATION: STANDARDIZED BY: OCM

PREPARED IN BAL. RES. LAB. A.P.G. -2-   KS 138

and shipping costs as low as possible. At the point of issue it is loaded to weight with sand and the spotting charge M1A1 is assembled to it before it is turned over to the Air Corps for use. In order to obtain the highest uniformity of flight of which the bombs are capable it is necessary that the variation in mechanical constants from bomb to bomb be kept as small as possible. In order to accomplish this, the bombs used in these range bombings were loaded with a mixture of sand and cinders in which the proportion of these two materials was adjusted to give the mixture a density such that the specified weight of the completely assembled bomb was obtained when the cavity of the bomb was completely filled. Before being loaded into the bomb the mixture was carefully blended in order to secure a uniform density.

The adequacy of this method of loading is indicated by the evidence cited in the next paragraph of this report and the relatively narrow probable error of forecast bands for the fitted relations between the ballistic coefficients and the altitude of release. These relations and the corresponding probable error of forecast bands are shown in Appendix D. If it is desired to obtain results of equal precision in the field it is recommended that a similar method of loading be prescribed. Failure to employ a systematic control in loading results in a wide dispersion in the mechahical constants of bombs and correspondingly wide dispersion in their flight characteristics.[1]

IV. Mechanical Constants of Bombs

The mechanical constants of each bomb were determined before it was loaded into the airplane. The detailed results of these measurements are given in Appendix A. A summary of the results obtained is given in the table below.

[1] A more complete description of the method used in order to control the mechanical constants of the bombs used in the range bombing program is given in a memorandum prepared in the Ballistic Research Laboratory: "Procedure for Determination of the Mechanical Constants of Bombs".

	m Weight Complete as Dropped lb.	$\bar{x}$ Distance of Center of Gravity from Nose in.	I_L Moment of Inertia about Longitudinal Axis[1] lb.ft.²	I_T Moment of Inertia about Transverse Axis through Center of Gravity lb.ft.²
Mean	99.3	18.14	5.410	76.06
Standard Deviation	0.85	0.24	0.052	1.31
Maximum	102.0	18.76	5.546	79.50
Minimum	98.0	17.75	5.294	72.64
Number of Bombs	99	99	41	99

These statistics refer to all bombs for which a ballistic coefficient with respect to any element was obtained. The actual variation in weight of these bombs does not affect the flight characteristics of the bombs sufficiently to cause a variation in ballistic coefficient large enough to be detected by the methods for estimating the ballistic coefficient which were used in the reduction of the field data. The variation in center of gravity position and moments of inertia would, if sufficiently in excess of that for the present bombs, affect the yaw of the bombs and thereby the dispersion in the elements range, time of flight and trail. The small dispersion in the mechanical constants for these bombs indicates the efficacy of the method of loading described in this report.[2]

V. Description of the Range Bombing

The bombs in this range bombing program were dropped from the B18, B-4, B-4A, B-18A and B-17B airplanes at a target anchored in Bush River in such a position that the release point was in the fields of view of the Vertical and Oblique Cameras Obscura. The direction of the approach to the release point on all runs was from southeast to northwest within approximately 15°.

On all approaches on which bombs were dropped, horizontal flight was maintained as nearly as possible. In the case of the B-18, B-18A, B-4 and B-4A the piloting was done by manual control. In the case of the B-17B airplane the piloting was done by automatic control.

[1] The spotting charge assembled to the Bomb, Practice, 100-lb., M38A2, was modified after 41 measures of I_L were made. The adapter used to permit axial rotation of the bomb in order to measure I_L could no longer be used and consequently only 41 measures of this moment of inertia were made.

[2] A more complete description of the method followed in controlling the mechanical constants is given in Ballistic Research Laboratory Report No. 190: "The Computation of the Mechanical Constants of Bombs".

In these airplanes the bomb racks are so arranged that the longitudinal axis of the bomb is nearly parallel to the thrust line of the airplane. Hence the initial yaw of the bomb in the vertical plane is nearly equal to the angle of attack of the airplane.

On all approaches with the B-18 and the B-18A airplane the bombs were carried in the rear bank of the bomb racks. The center line of this rack is 12.8 feet to the rear of the point formed by the junction of the front edge of the wing with the fuselage of the airplane at which point the airplane is plotted in the cameras obscura. In the B-4 airplane there is a single bank of bomb racks. The corresponding distance is 3.7 feet.[1] In the B-17B airplane the corresponding distance is 6.4 feet for all the bomb rack stations used in range bombing.

All bombs were dropped according to the current standard bombing practice of the Air Corps using the current standard bomb sight and a target in Bush River as an aiming point. The adequacy of the bombing technique is indicated by the results shown in Appendix B. The displacement of the center of impact with respect to the target results in part from the fact that the bombing tables available to the bombardier were based on roughly approximated values of the ballistic coefficients and, for the purpose of this report, are of no special significance. The dispersion about the center of impact and other data summarized in Appendix B are, however, of considerable interest.

The bombs dropped were divided into groups and the endeavor made to make the altitude and air speed within a group approximate as nearly as possible to certain specified values. These values were described as the standard altitude and standard air speed.[2]

The number of bombs in each group and the standard altitude and air speed for each group are given in Appendix D. The reasons for the selection of these standard altitudes and air speeds are given in sections VI and IX of this report.

[1] The effect of the bomb bay release position on the estimated values of the ballistic coefficients is discussed in Ballistic Research Laboratory Report No. 136: "First Progress Report: On the Method of Reduction of Observations on the Elements of Bomb Trajectories".

[2] Compare the usage of these terms for statistical purposes in Sections VIII and IX of this report.

The range bombing was conducted by the following:

Pilots:

        Capt. D. W. Watkins, A.C.
        Capt. C. S. Thorpe, A.C.
        First Lt. L. H. Tull, A.C.
        First Lt. B. A. Schreirer, A.C.
        Second Lt. C. A. Peterson, A.C.
        W.O., J. A. Lee, Sr.
        Master Sgt. S. C. Smink, A.C.

Bombardiers:

        Capt. C. S. Thorpe, A.C.
        First Lt. M. F. Summerfelt, A.C.
        Master Sgt. S. C. Smink, A.C.

Proof Officers:

        First Lt. R. G. Butler, O.D.
        First Lt. J. H. Weber, O.D.
        First Lt. J. A. Barclay, Jr., O.D.
        First Lt. J. D. Armitage, O.D.
        First Lt. J. G. Shinkle, O.D.

VI.   Ground Observations

The primary ground observational equipment employed was the Camera Obscura Installation.[1] The position of the aircraft in space and its components of velocity were fundamental data obtained by reduction of observations made with this equipment.

The field data for determination of times of flight were secured by the chronograph installation housed in the Vertical Camera Obscura. The instants of release and impact were recorded by this chronograph – hydrophone system which has been in use in the present form since 1937.[2]

[1] The basic description of the Camera Obscura Installation is given in the "First, Second and Third Progress Reports on Bomb Trajectory Study by the Camera Obscura Method" by Frank Short, F. V. Ludden and S. P. Willan. The equipment has been extensively modified and improved during 1938 and the current equipment and accuracy are described in the Ballistic Research Laboratory Report No. 144: "First Progress Report: On the Accuracy of the Camera Obscura Installation for Obtaining the Initial Data of Bomb Ballistics".

[2] The calibration of the chronograph-hydrophone system and the measurement of the systematic errors to which it is subject were carried out in 1938 and are described in Ballistic Research Laboratory Report No. 130: "On the Measurement of the Time of Flight of Bombs". The absolute accuracy and internal precision of the method in actual practice has been recently determined and the results are given in Ballistic Research Laboratory Report No. 211: "Comparison of Measures of the Time of Flight of Bombs by the Camera Obscura Chronograph and the Western Electric Clock".

The coordinates of the impacts referred to the camera coordinate system were obtained by the ground observers by means of three azimuth instruments on towers along the shore of Bush River and furnished to the Bombing Unit of the Ballistic Research Laboratory. The dispersion data with reference to the target, the reduced meteorological data for securing corrections to the elements tabulated in the bombardier's approximate bombing tables, and the corrections obtained from these meteorological data were also provided by the ground observers. The latter graphically summarized results are given in Appendix B, "Primary Results of Range Bombing".

The field data necessary for the reduction of the effects of non-standard meteorological conditions were obtained from two sources. The data secured by the camera observers were the coordinates on the camera plotting boards of smoke puffs at regular intervals for a series of altitudes, the velocity and direction of the wind at the surface of the ground and the barometric pressure of the air at the surface of the ground. The data secured by the Range Observation Section observers were the spatial positions of a balloon at regular intervals and the velocity and direction of the wind at the surface of the ground. The temperature and barometric pressure at a series of altitudes above the ground were obtained from the bombing flight records of the bombardier. These data were partially reduced by the Range Observation Section and were furnished to the Bombing Unit in the form of tables of:

(1)   The actual wind components, and

(2)   The density of the air relative to standard ordnance air density structure, each at a series of altitudes.

The wind components were taken as positive along the bombing lane and to the right of the bombing lane. The bombs were dropped during the interval between two wind measurements.

Field data on range bombing with the Bomb, Practice, 100-lb., M38A2 were obtained in part from the program carried out between May 21, 1937 and May 25, 1938. A systematic bombing program was selected containing four altitude groupings at 6,000, 9,000, 12,000 and 15,000 feet and carried out between March 9, 1938 and May 25, 1938. The advance of ballistic theory and increased accuracy of measurement during 1938 and

1939 showed that better results can be obtained from group-
ings at a great altitude of release, a central altitude and
a low altitude. Consequently the range bombing program for
this bomb was extended during 1939 to include groups at al-
titudes of release of 20,000 feet and 2,000 feet. These bombs
were dropped during the interval between May 3, 1939 and
July 17, 1939. In addition, data drawn from the program for
determination of the effect of speed of release upon ballistic
coefficient for the M38A2 at 7,000 feet altitude of release
have been employed. This program was carried out between
October 31, 1938 and November 10, 1938. On June 21 and July 5,
1940 range bombing was obtained at an approximate altitude
of 25,000 feet. Field data were obtained for determinations
of range and time of flight for 99 bombs. Trail determina-
tions were made from the reduced ranges and times of flight
when it was possible. A total of 82 times of flight and 82
trails were obtained.

VII. Reduction of Field Data

The data secured by the ground observers at the cameras
were utilized to obtain the position and velocity of the
airplane at the instant of release. The data secured by the
ground observers at the azimuth instruments were utilized
to obtain the position of impact of the bombs. The time
interval resulting from the chronograph strip was employed
to determine the uncorrected interval in time. These data
were then corrected for instrumental errors.[1]

VIII. Determination of Ballistic Coefficient

The reduction of the field data furnishes values of
the range and time of flight corresponding to a certain set
of known values of altitude and air speed, but containing the
effects of departures from standard ballistic table conditions.[2]
The preparation of a bombing table requires a set of elements
which are correct under standard bombing table conditions.
The effects of departures from standard bombing table conditions
must in the main be removed from the unreduced ranges and
times of flight. When standard ballistic table conditions
differ from standard bombing table conditions, the effects
of these differences are allowed to remain in the reduced
ranges and times of flight. The preparation of the bombing
table requires the equivalent of a knowledge of the range and
time of flight corresponding to all attainable altitudes and
air speeds. The procedure is to determine values of the

[1] The character of these instrumental errors is discussed in Ballistic
Research Laboratory Reports No. 144, 130 and 211, previously cited.

[2] Standard ballistic table conditions and standard bombing table conditions
are discussed and compared in Ballistic Research Laboratory Report No. 145:
"On the Theory of Motion of the Bomb".

ballistic coefficients for the observed elements and compute bombing table elements for the other cases by interpolation or extrapolation of the ballistic coefficients.[1]

The computation of the ballistic coefficients is carried out by means of a Bomb Ballistic Reduction Table.[2] The standard ballistic table conditions under which the Bomb Ballistic Reduction Table is computed include the assumption that the only air force acting on the bomb is the drag and that this depends on velocity according to the Gâvre law. Because of these and other differences between standard ballistic table conditions and standard bombing table conditions, there occur not only variations in C with altitude and air speed but the value of C required to give the correct range is different from that required to give the correct time of flight and that for trail is different from either.[3]

In accordance with these principles the ballistic coefficients corresponding to the ranges, times of flight, and trails were then deduced for each individual bomb. From these coefficients the ranges, times of flight and trails were computed for the standard altitude and standard air speed of the group to which the bomb belonged. These are called the "standard ranges", "standard times of flight" and "standard trails", or in general the "standard elements" and are given in Appendix C together with the corresponding ballistic coefficients. This appendix also lists the program, the group, the serial number stamped on the bomb, the date of release and the run number which is called "Bomb No." in "Results of Range Bombing" contained in Appendix B. The last two provide for comparison with Appendices A and B.

The standard elements and the ballistic coefficients corresponding thereto contain the effects of certain unknown instrumental inaccuracies and of certain departures from standard bombing table conditions which it was not feasible to remove in advance. However, the effects of these sources of dispersion were partially removed by the process used for the construction of the bombing table.

[1] The method of reduction of field data in order to obtain ballistic coefficients with respect to range, time of flight and trail has undergone considerable evolution. The reports from which the present methods were developed include: Ballistic Research Laboratory File E-IV-3: "Explanations and Comparisons of the Camera Obscura Methods of Computation", *Computation of Firing Tables for the U.S. Army" and Ballistic Research Laboratory Report No. 136, previously cited.

[2] The table used in reduction of the data discussed in this report was prepared in the Ballistic Research Laboratory.

[3] A discussion of the ballistic coefficients corresponding to range, time of flight and trail is given in Ballistic Research Laboratory Report No. 143: "Errors in Trail Resulting From Ignoring Either the Measured Range or the Measured Time of Flight".

IX. Construction of Tables

The experimental data from which the ballistic coefficients with respect to range, time of flight and trail were determined, fell into 8 altitude groups. The groups were for standard release altitudes of 25,000, 20,000, 15,000, 12,000, 9,000, 7,000, 6,000 and 2,000 feet. The groups at 15,000, 12,000, 9,000 and 6,000 feet were employed in construction of the Bombing Table BT-100-B-1. They were all obtained during 1938. The 7,000 foot groups were obtained incidentally to the range bombing program undertaken to determine the effect of speed of release upon ballistic coefficient. The later bombing programs were determined uniformly for release altitudes of 2,000, 10,000 and the maximum obtainable since it was found that this plan resulted in the greatest amount of ballistic information with the greatest economy in the bombing program. Consequently the range bombing program of 1939 added the groups at 20,000 and 2,000 feet. In 1940 range bombing was carried out for an altitude group of 25,000 feet. The dependence of the ballistic coefficients upon altitude of release were thus well determined.

The mean standard elements for a standard true air speed and altitude were determined for each altitude group. The mean standard element is the arithmetic mean of the individual standard elements. The individual standard elements used in computing the mean standard elements had of course, been reduced to the group standard altitude and true air speed. The use of the mean standard elements reduces the influence of accidental errors in the individual standard elements upon the elements tabulated in the bombing table. The ballistic coefficients corresponding to these mean standard elements were then deduced. The forms of the functional dependence upon altitude of the three ballistic coefficients have been derived theoretically and verified empirically.[1] The lift is the cause mainly responsible for the character of the variation of the ballistic coefficients with altitude. The lift is due to the yaw arising from the initial angular velocity of the tangent to the trajectory. The effects of lift are allowed to remain in the ballistic coefficients corresponding to the mean standard elements. The functional relations referred to are:

---

[1] The derivation of the form of these relations between the ballistic coefficient and the altitude of release is discussed in Ballistic Research Laboratory Report No. 145, previously cited.

$$C_{X_y} = \frac{C_{X_\infty}}{1 + \dfrac{k_X C_{X_\infty}}{\sqrt{Y}}}$$

$$C_{T_y} = \frac{C_{T_\infty}}{1 + \dfrac{k_T C_{T_\infty}}{\sqrt{Y}}}$$

$$C_{\lambda_y} = \frac{C_{\lambda_\infty}}{1 + \dfrac{k_\lambda C_{\lambda_\infty}}{\sqrt{Y}}}$$

These curves each contain two empirical quantities k and C_∞. The subscript ∞ refers to the mean effective ballistic coefficient for infinite altitude, and k is a parameter determining the shape of the curve.

A new procedure for estimating the values of C_{X_∞}, C_{T_∞}, C_{λ_∞}, k_X, k_T and k_λ was introduced between the date when bombing tables BT-100-B-2 were issued and the date when bombing tables BT-100-B-3 were issued.[1] The new procedure involved two principal modifications in the method of estimation:

(1) An improved assignment of weights to the altitude groups, and
(2) Direct minimization of the weighted squares of the residual differences between the mean standard elements and those elements which would result from the use of the bombing tables. This modification has resulted in much smaller probable ballistic errors for bombing tables.[2] The improvement is shown by the reduced magnitude of the differences between the observed mean standard ranges, times of flight and trails and those elements which would result from employment of these tables. The values C_{X_∞}, C_{T_∞}, C_{λ_∞}, k_X and k_λ were deduced by this new procedure: k_T was shown to be without significance in the present instance.

[1] A brief description of the new procedure is given in Ballistic Research Laboratory Report No. 224: "Experimental Data Forming the Basis for the Bombing Tables BT-1000-A-1 for the Bomb, Demolition, 1000-lb., M44".
[2] The ballistic error is a term originally used by British ballisticians to denote the difference between the bombing table range and the mean standard range for the same conditions. The ballistic error is denoted by $X - X_f$ in this report.

The values were:

$$C_{X_\infty} = 1.223 \; ; \; C_{T_\infty} = 1.290 \; ; \; C_{\lambda_\infty} = 1.171$$

$$k_X = -20.692; \; k_T = 0 \quad ; \; k_\lambda = -17.889$$

The observed and fitted ballistic coefficients are compared in Tables 1, 2 and 3 of Appendix D. The relations between the fitted ballistic coefficients and the altitude of release are shown in Plots I, II and III in Appendix D. The fitting provides for obtaining the ballistic coefficient for any altitude of release. The actual points on the plots in Appendix D are shown by dots and their probable errors by horizontal strokes placed on the sides of the dots. The computed C : Y relations are shown by heavy lines. The dotted lines furnish the probable error of forecast. The band included by these lines is determined by addition and subtraction of the probable error of the computed C : Y relation from the curve.

The construction of the table of DS followed general instructions given in file 00 063.2/4524 (Confidential). The trail angles, times of flight and dropping angles tabulated were obtained by interpolation with the fitted C : Y relations in the Bomb Ballistic Auxiliary Tables (Provisional) computed in the Ballistic Research Laboratory. These tables give trail angles, times of flight and dropping angles as functions of the altitude of release, Y, the calibrated indicated air speed, V, or true ground speed, V_g, and the reciprocal ballistic coefficient, $\frac{1}{C}$. The intervals of the arguments used in the Bomb Ballistic Auxiliary Tables are the same as those used in the present series of abridged bombing tables. The small differences between the observed mean standard ranges, times of flight and trails and those elements which would result from employment of these tables are shown by the columns $X - X_f$, $T - T_f$ and $\lambda - \lambda_f$ given in Tables 1, 2 and 3 of Appendix D. These differences are compared with the probable errors of the observed mean standard elements in Plots IV, V and VI of Appendix D. The importance of employment of the fitted C_{X_y} : Y, C_{T_y} : Y and C_{λ_y} : Y curves is shown by the small magnitudes of these differences.

The bombing tables BT-100-B-3 are a revision of bombing tables BT-100-B-2. The ranges of arguments included in these bombing tables are indicated in the table below:

Element	Speed mi./hr.		Altitude ft.	
	Minimum	Maximum	Minimum	Maximum
Trail Angle (Calibrated Indicated Air Speed)	100	250	1800	35000
DS (Calibrated Indicated Air Speed)	4580 5300	160	1800 1800	21000 31000
Time of Flight (Calibrated Indicated Air Speed)		160	1000	35000
Dropping Angle (Ground Speed)	100	250	100	10000

The Introduction to the bombing tables BT-100-B-3 has been shortened to one page and contains only the most essential information.

E. S. Martin

Ellen Boyle

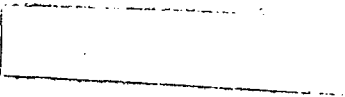Appendix A

Mechanical Constants of Bombs

Appendix A

Mechanical Constants of Bombs

Program, Group, Serial Number	Date of Release, Run Number	m Weight Complete as Dropped	$\bar{x}$ Distance of Center of Gravity From Nose	I_L Moment of Inertia About Longitudinal Axis	I_T Moment of Inertia About Transverse Axis Through Center of Gravity
		lb.	in.	lb.ft.^{2}	lb.ft.^{2}
KS-138L-9	3/9/38--1	99	17.75	5.480	75.24
8	2	99	17.87	5.438	73.78
12	3	99	17.75	5.384	74.36
10	4	99	17.87	5.438	75.06
11	5	99	17.87	5.390	74.99
7	6	99	17.87	5.428	73.84
KS-138-13	3/21/38-1	99	18.00	5.404	73.72
18	2	99	17.87	5.410	77.80
14	3	99	18.00	5.412	75.12
17	4	99	17.81	5.464	76.12
16	6	99	17.81	5.386	76.53
19	4/25/38-1	100	17.75	5.434	74.96
20	2	100	18.25	5.402	77.02
22	4	100	18.12	5.408	76.60
23	5	100	17.81	5.452	75.39
24	4/28/38-1	99	18.06	5.464	76.10
26	3	99	17.94	5.524	73.31
31	4	99	17.94	5.425	76.02
37	5	99	18.37	5.360	76.60
32	6	99	18.03	5.411	75.63
28	5/2/38--1	99	18.12	5.383	76.48
36	2	99	18.12	5.312	76.46
33	3	99	18.37	5.294	76.15
37	4	99	17.87	5.353	75.31
34	5	99	18.00	5.320	75.70
38	5/3/38--1	99	18.25	5.396	75.40
39	2	99	18.00	5.470	72.68
40	3	99	18.12	5.410	75.85
41	4	99	17.94	5.392	75.66
42	5	99	17.94	5.406	78.12
43	6	99	18.06	5.382	75.98
35	5/6/38--1	99	17.87	5.395	76.85
48	2	99	18.00	5.445	75.55
44	3	99	18.50	5.378	75.72
49	4	99	18.22	5.546	75.80
46	5	99	18.00	5.316	76.82
53	5/25/38-1	99	18.45	5.483	75.35
54	2	99	18.60	5.361	74.27
55	3	99	18.55	5.425	74.20
52	4	99	18.60	5.429	75.48
51	5	99	18.40	5.395	74.39

Mechanical Constants of Bombs

Program, Group, Serial Number	Date of Release, Run Number	m Weight Complete as Dropped lb.	$\bar{x}$ Distance of Center of Gravity From Nose in.	I_L Moment of Inertia About Longitudinal Axis lb.ft.²	I_T Moment of Inertia About Transverse Axis Through Center of Gravity lb.ft.²
RX-138-107	10/31/38--1	100.0	18.32		76.39
112	2	100.8	18.40		77.77
109	3	99.5	18.43		78.47
110	4	100.0	18.50		77.19
111	5	99.8	18.76		78.03
102	1	98.5	18.46		76.66
103	2	99.8	18.57		77.25
104	3	99.0	18.29		76.74
105	4	99.9	18.75		78.61
106	5	99.8	18.40		77.34
108	11/10/38--1	99.5	18.48		77.76
113	2	100.1	18.31		78.45
114	3	99.1	18.42		77.34
115	4	99.5	18.42		77.06
116	5	100.3	18.50		77.85
117	1	100.9	18.23		77.33
118	2	100.8	18.52		77.30
119	3	100.2	18.32		76.89
120	4	100.4	18.45		76.95
121	5	99.5	18.44		78.39
KS-138---1	5/3/39----1	98.0	17.87		75.42
2	2	98.0	18.20		75.09
3	3	99.5	17.89		77.04
4	4	98.0	17.92		76.54
7	5	98.0	18.02		74.63
6	6	99.0	18.22		75.68
9	7	99.0	18.10		75.68
8	8	98.0	18.07		74.83
10	9	98.2	17.96		74.33
5	10	99.0	17.85		75.73
11	5/4/39----1	98.5	17.81		79.50
12	2	100.0	18.22		77.10
13	3	100.0	18.11		77758
14	4	98.0	18.10		77.57
15	5	99.0	18.20		76.87
16	6	98.0	17.90		76.28
17	7	98.0	17.75		76.20
18	8	98.0	18.07		77.52
19	9	98.0	18.25		77.56
20	10	98.2	18.11		76.92

Mechanical Constants of Bombs

Program, Group, Serial Number	Date of Release, Run Number	m Weight Complete as Dropped lb.	x̄ Distance of Center of Gravity From Nose in.	I_L Moment of Inertia About Longitudinal Axis lb.ft.²	I_T Moment of Inertia About Transverse Axis Through Center of Gravity lb.ft.²
KS-138-1	7/11/39-1	99.0	18.25		74.73
2	2	99.0	18.07		75.33
3	3	99.5	18.14		74.57
4	4	99.5	18.00		75.35
5	5	98.5	18.25		74.45
6	6	99.5	18.14		74.96
7	7	101.0	18.25		75.43
8	8	102.0	18.27		75.90
9	7/17/39-1	102.0	18.10		76.28
10	2	98.0	18.08		72.64
1	6/21/40-1	101.0	18.03		75.75
2	2	101.0	17.91		75.48
4	4	101.0	18.14		75.91
5	5	99.0	17.86		74.87
7	7/5/40--2	100.0	18.01		75.23
8	3	100.0	18.16		75.39
9	4	99.5	18.18		75.62
10	5	100.5	18.01		75.42

Appendix B

Primary Results of Range Bombing

RESULTS OF RANGE BOMBING NO. 1

MARCH 9, 1938   100 LB. PRACTICE BOMB M38A2   AIRPLANE B18

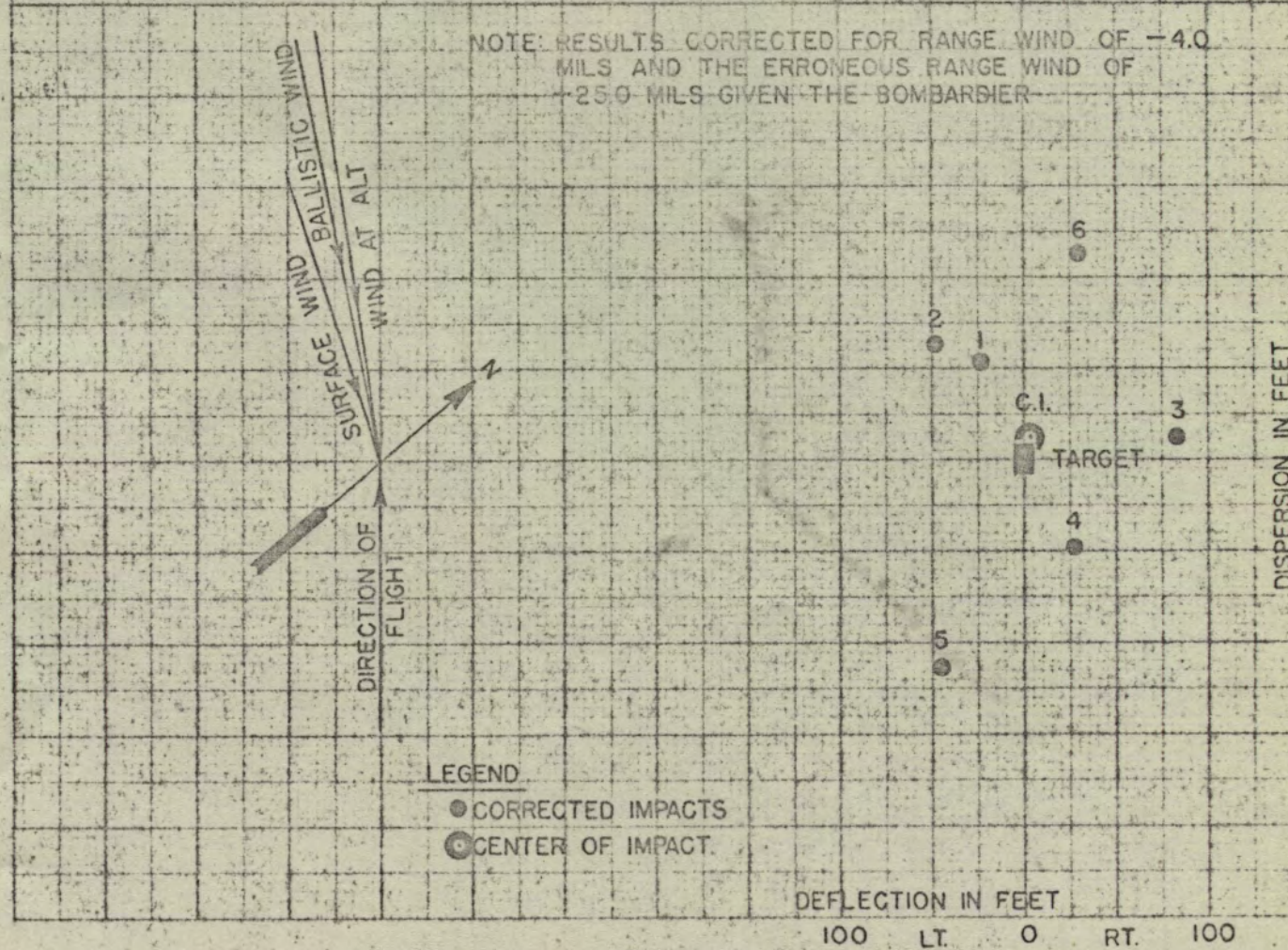PILOT: CAPT. D. W. WATKINS (1-4), W. O. J. A. LEE (5&6)   BOMBARDIER: CAPT. C. S. THORP

SKY: AIR   TRAIL AND D.S. BASED ON C = 1.4

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GRND. SPEED GRND. OBS. M/HR	CLIMB-GLIDE		DEVIATIONS FROM TAR			
		AIR OBS FT.	GRND. OBS FT.	CAL. IND M/HR	TRUE			AIR OBS	GRND. OBS	RANGE		DEFLECT	
					AIR OBS. M/HR	GRND. OBS. M/HR		FT/MIN	FT/MIN	OVER FT.	SHORT FT.	RIGHT FT.	L
1	11:05	8810	8800	146	167.3	163.9	105.7		+ 6.6	309			
2	11:05	8810	8800	146	167.3	163.9	105.7		+ 6.6	318			
3	11:15	8840	8813	145	166.2	160.7	102.3		-81.6	270		84	
4	11:25	8810	8773	144	164.9	161.7	103.7		-73.8	204		27	
5	11:35	8800	8769	148	169.5	167.0	108.4		-75.6	144			
6	11:45	8850	8843	148	169.8	165.1	106.8		-63.6	369		30	
								CENTER OF IMPACT		269		4	
								MEAN DEVIATION			63		43

	TIME	9:51	1:35	CORRECTIONS USED		
WIND	SURFACE, VELOCITY (M/HR)	7.0	13.0	MILS IN	RANGE	DEF
	AT ALTITUDE, VELOCITY "	56.8	93.7			
	BALLISTIC VELOCITY "	49.6	66.4	WIND	+25.0	0.4
	BALLISTIC AZIMUTH (TO)	298.4°	289.0°			
DENSITY	AT SURFACE	1.061	1.046	DENSITY	—	—
	BALLISTIC (SURFACE)	1.047	1.037			
	BALLISTIC (AIR OBS.)	1.041	1.032	TOTAL	+25.0	0.4

NOTE: AN ERRONEOUS RANGE WIND OF
+25.0 MILS WAS GIVEN THE
BOMBARDIER

LEGEND
⬭ ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)
⬭ ACTUAL CENTER OF IMPACT

BALLISTIC WIND
WIND AT ALT.
SURFACE WIND

DIRECTION OF FLIGHT

TARGET

DEFLECTION IN FEET
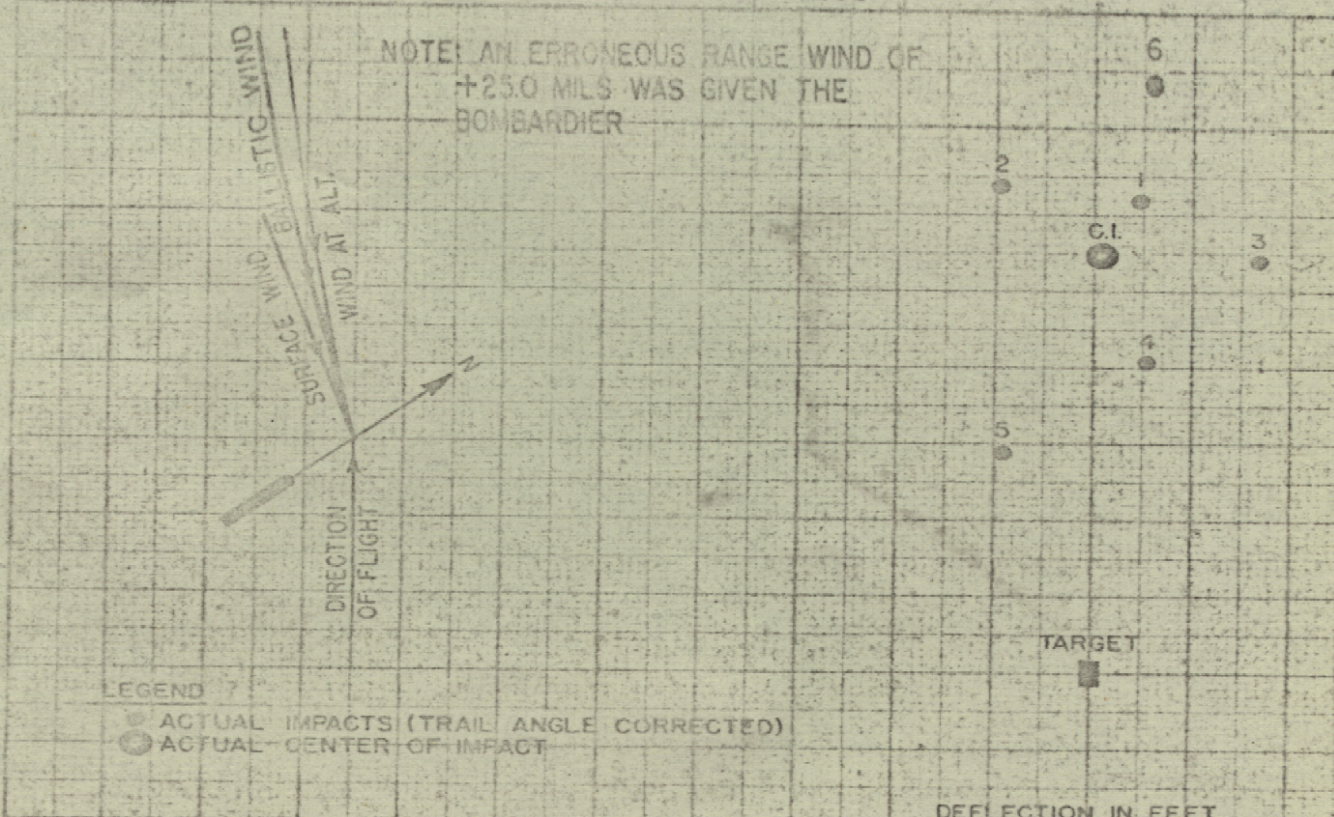
RESULTS OF RANGE BOMBING NO. 1A

MARCH 9, 1938   100 LB. PRACTICE BOMB M38A2   AIRPLANE B18

PILOT: CAPT. D. W. WATKINS (1-4), W. O. J. A. LEE (5 & 6)   BOMBARDIER: CAPT. C. S. THORPE

SKY: AIR: TRAIL AND D.S. BASED ON C = 1.41

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GRND. SPEED GRND. OBS. M/HR	CLIMB-GLIDE		DEVIATIONS FROM TARGET			
		AIR OBS. FT.	GR'ND OBS. FT.	CAL. IND. M/HR	TRUE			AIR OBS. FT/MIN.	GR'ND OBS. FT/MIN.	RANGE		DEFLECTION	
					AIR OBS. M/HR	GRND. OBS. M/HR				OVER FT.	SHORT FT.	RIGHT FT.	LEFT FT.
1	11:05	8810	8800	146	167.3	163.9	105.7		+ 6.6	54			24
2	11:05	8810	8800	146	167.3	163.9	105.7		+ 6.6	63			48
3	11:15	8840	8813	145	166.2	160.7	102.3		−81.6	12		84	
4	11:25	8810	8773	144	164.9	161.7	103.7		−73.8		48	27	
5	11:35	8800	8769	148	169.5	167.0	108.4		−75.6		114		45
6	11:45	8850	8843	148	169.8	165.1	106.8		−63.6	111		30	
									CENTER OF IMPACT	13		4	
									MEAN DEVIATION	63		43	

	TIME	9:51	1:35	CORRECTIONS USED		
				MILS IN	RANGE	DEFL.
WIND	SURFACE, VELOCITY (M/HR)	7.0	13.0			
	AT ALTITUDE, VELOCITY "	56.8	93.7	WIND	—	—
	BALLISTIC { VELOCITY "	49.6	66.4			
	BALLISTIC { AZIMUTH (TO)	298.4°	289.0°	DENSITY	—	—
DENSITY	AT SURFACE	1.061	1.046			
	BALLISTIC (SURFACE)	1.047	1.037	TOTAL	—	—
	BALLISTIC (AIR OBS.)	1.041	1.032			

NOTE: RESULTS CORRECTED FOR RANGE WIND OF −4.0 MILS AND THE ERRONEOUS RANGE WIND OF 25.0 MILS GIVEN THE BOMBARDIER

BALLISTIC WIND

WIND AT ALT

SURFACE WIND

DIRECTION OF FLIGHT

DISPERSION IN FEET

DEFLECTION IN FEET

100 LT. 0 RT. 100

LEGEND
CORRECTED IMPACTS
CENTER OF IMPACT

RESULTS OF RANGE BOMBING NO. 2

MARCH 21, 1938   100 LB PRACTICE BOMB M38A2   AIRPLANE B18

PILOT W. O. J. A. LEE.   BOMBARDIER CAPT. C. S. THORPE.

SKY: AIR: TRAIL AND D.S. BASED ON C = 1.41

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GRND OBS. FT.	AIR SPEED CAL. IND. M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GRND OBS. M/HR	GRND SPEED GRND OBS. M/HR	CLIMB-GLIDE AIR OBS. FT/MIN.	CLIMB-GLIDE GRND OBS. FT/MIN.	RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1	10:50	9200	9270	140.7	162.4	159.1	135.7		-196.2	54			123
2	11:00	9200	9261	145.0	167.3	165.4	142.0		-227.4	33			234
3	11:15	9200	9265	146.0	168.5	166.0	142.6		- 85.2	117			270
4	11:30	9180	9255	144.0	166.2	162.8	139.3		- 31.2		15		177
5		9160		140.7	162.4					30			339
6	12:00	9180	9236	140.7	162.4	158.7	135.4		+ 10.2		186		57

DIFFERENTIAL BALLISTIC WIND M/HR.   CENTER OF IMPACT   6   200

RANGE: -5.5   CROSS: +4.7   MEAN DEVIATION   71   81

	TIME	9:36	1:30	CORRECTIONS USED		
WIND	SURFACE VELOCITY (M/HR)	8.0	6.6	MILS IN	RANGE	DEFL.
	AT ALTITUDE VELOCITY	29.6	18.0			
	BALLISTIC VELOCITY	23.0	15.8	WIND	-3.0	2.0R
	BALLISTIC AZIMUTH (TO)	300.7°	307.1°			
DENSITY	AT SURFACE	1.004	0.995	DENSITY	—	—
	BALLISTIC (SURFACE)	1.009	1.003			
	BALLISTIC (AIR OBS.)	0.993	0.990	TOTAL	-3.0	2.0 R
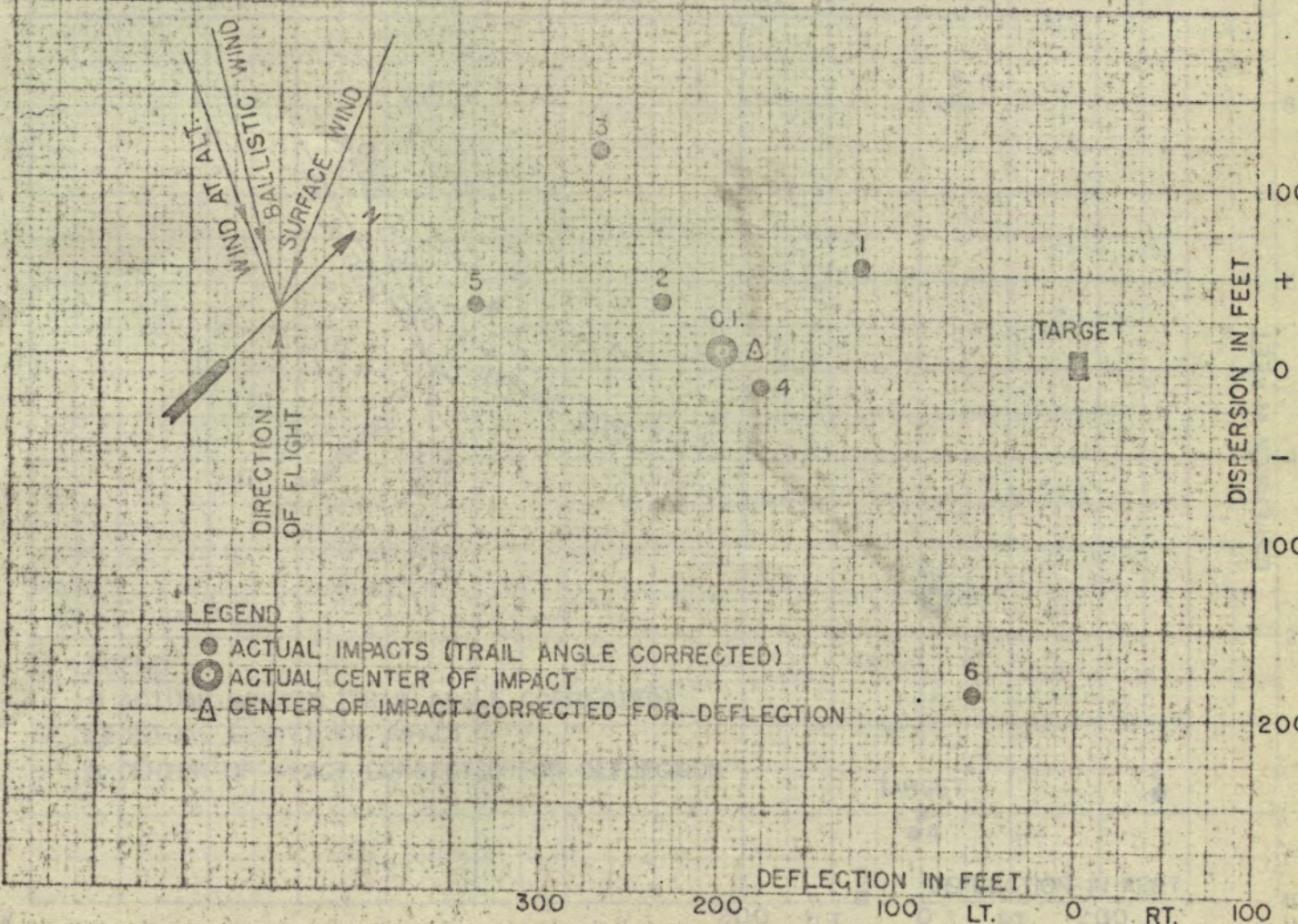
LEGEND
⊙ ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)
⊚ ACTUAL CENTER OF IMPACT
△ CENTER OF IMPACT CORRECTED FOR DEFLECTION

DIRECTION OF FLIGHT

WIND AT ALT.   BALLISTIC WIND   SURFACE WIND

DISPERSION IN FEET

DEFLECTION IN FEET

300   200   100   LT.   0   RT.   100

RESULTS OF RANGE BOMBING NO. 5

APRIL 25, 1938   **100 LB. PRACTICE BOMB M38A2**   **AIRPLANE B 18**
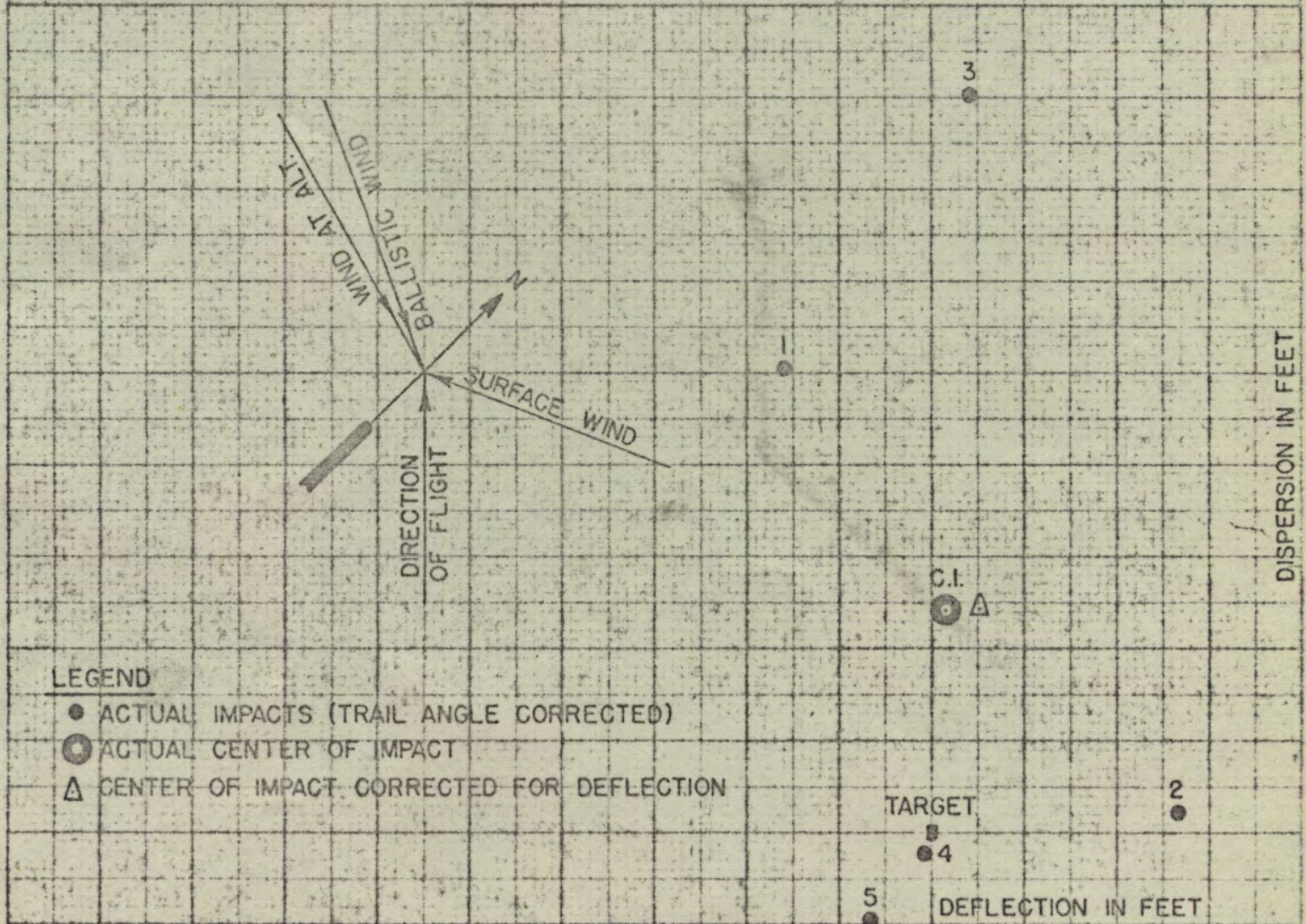
PILOT: CAPT. D. W. WATKINS   BOMBARDIER: CAPT. C. S. THORPE
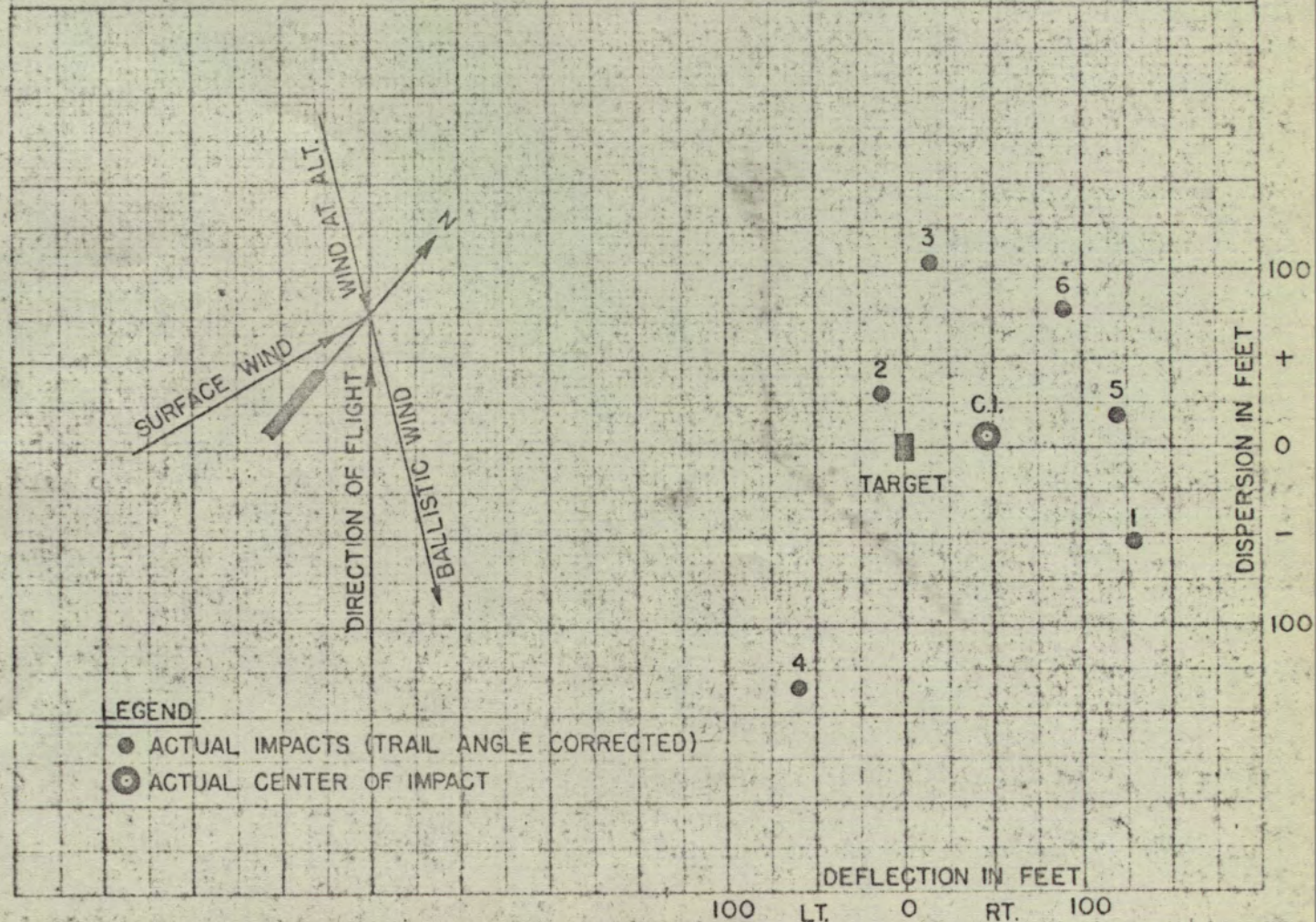
SKY: AIR: TRAIL AND D.S. BASED ON C = 1.60

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GRND. SPEED	CLIMB-GLIDE		DEVIATIONS FROM TARGET			
		AIR OBS.	GRND. OBS.	CAL. IND.	TRUE		GRND. OBS.	AIR OBS.	GRND. OBS.	RANGE		DEFLECTION	
					AIR OBS.	GRND. OBS.				OVER	SHORT	RIGHT	LEFT
		FT.	FT.	M/HR	M/HR	M/HR	M/HR	FT/MIN	FT/MIN	FT.	FT.	FT.	FT.
1	10:50	12320	12283	144	173.7	174.7	140.9		+23.4	504			159
2	11:00	12340	12301	143	172.5	169.0	137.3		+19.2	21		267	
3	11:06	12320	12263	141	169.9	171.5	140.0		+52.2	801		42	
4	11:20	12340	12296	145	174.9	173.8	143.9		-28.2		24		9
5	11:41	12340	12309	145	174.9	170.0	142.2		+117.6		96		66
6													

DIFFERENTIAL BALLISTIC WIND M/HR.   CENTER OF IMPACT   241   15

RANGE: -5.7   CROSS: +8.2   MEAN DEVIATION   329   112

		TIME	10:03	12:35	CORRECTIONS USED		
WIND	SURFACE, VELOCITY (M/HR)		6.0	6.0	MILS IN	RANGE	DEFL.
	AT ALTITUDE, VELOCITY "		34.0	29.5			
	BALLISTIC: VELOCITY "		25.2	27.3	WIND	-2.7	3.0 R
	AZIMUTH (TO)		293.0°	304.3°			
DENSITY	AT SURFACE		1.028	1.016	DENSITY	+2.2	—
	BALLISTIC (SURFACE)		1.024	1.017			
	BALLISTIC (AIR OBS.)		0.996	0.991	TOTAL	-0.5	3.0 R

LEGEND
- ● ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)
- ◎ ACTUAL CENTER OF IMPACT
- △ CENTER OF IMPACT CORRECTED FOR DEFLECTION

DISPERSION IN FEET

DEFLECTION IN FEET

200 LT. 0 RT. 200

RESULTS OF RANGE BOMBING, NO. 6

APRIL 28, 1938   100 LB. PRACTICE BOMB M38A2   AIRPLANE B-18

PILOT. LT. L. H. TULL   BOMBARDIER: CAPT. C. S. THORPE

SKY: AIR: TRAIL AND D.S. BASED ON C = 1.60

| BOMB NO. | TIME OF REL. | ALTITUDE | | AIR SPEED | | | GRND. SPEED GRND. OBS. M/HR | CLIMB-GLIDE | | DEVIATIONS FROM TARGET | | | |
| | | AIR OBS. FT | GR'ND. OBS. FT | CAL. IND. M/HR | TRUE | | | AIR OBS. FT/MIN | GR'ND. OBS. FT/MIN | RANGE | | DEFLECTION | |
					AIR OBS. M/HR	GR'ND OBS. M/HR				OVER FT	SHORT FT	RIGHT FT	LEFT FT
1	10:55	6270	6162	140	153.7	148.6	143.2		+ 27.6		54	129	
2		6270		141						30			12
3	11:25	6270	6373	143	157.6	158.3	154.2		- 67.2	105		15	
4	11:33	6270	6349	140	154.3	153.3	150.1		-100.2		135		60
5	11:40	6270	6305			154.0	151.4		+143.4	18		120	
6	11:55	6270	6270	148	162.8	168.1	162.7		+110.4	78		90	

DIFFERENTIAL BALLISTIC WIND M/HR.   CENTER OF IMPACT   7   47

RANGE: −0.7   CROSS: +0.4   MEAN DEVIATION   68   66

		TIME	9:38	12:00	CORRECTIONS USED		
WIND	SURFACE VELOCITY (M/HR)		14.0	14.0	MILS IN	RANGE	DEFL.
	AT ALTITUDE VELOCITY "		9.9	4.1			
	BALLISTIC { VELOCITY "		9.2	3.3	WIND	−0.3	0.1 R
	AZIMUTH (TO)		306.5°	261.3°			
DENSITY	AT SURFACE		0.998	0.984	DENSITY	+0.1	—
	BALLISTIC (SURFACE)		1.003	0.992			
	BALLISTIC (AIR OBS.)		0.985	0.980	TOTAL	−0.2	0.1 R

LEGEND
- ● ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)
- ◎ ACTUAL CENTER OF IMPACT

DISPERSION IN FEET

DEFLECTION IN FEET
100 LT.   O   RT. 100

RESULTS OF RANGE BOMBING NO. 7

MAY 2, 1938   100 LB. PRACTICE BOMB M38A2   AIRPLANE B18

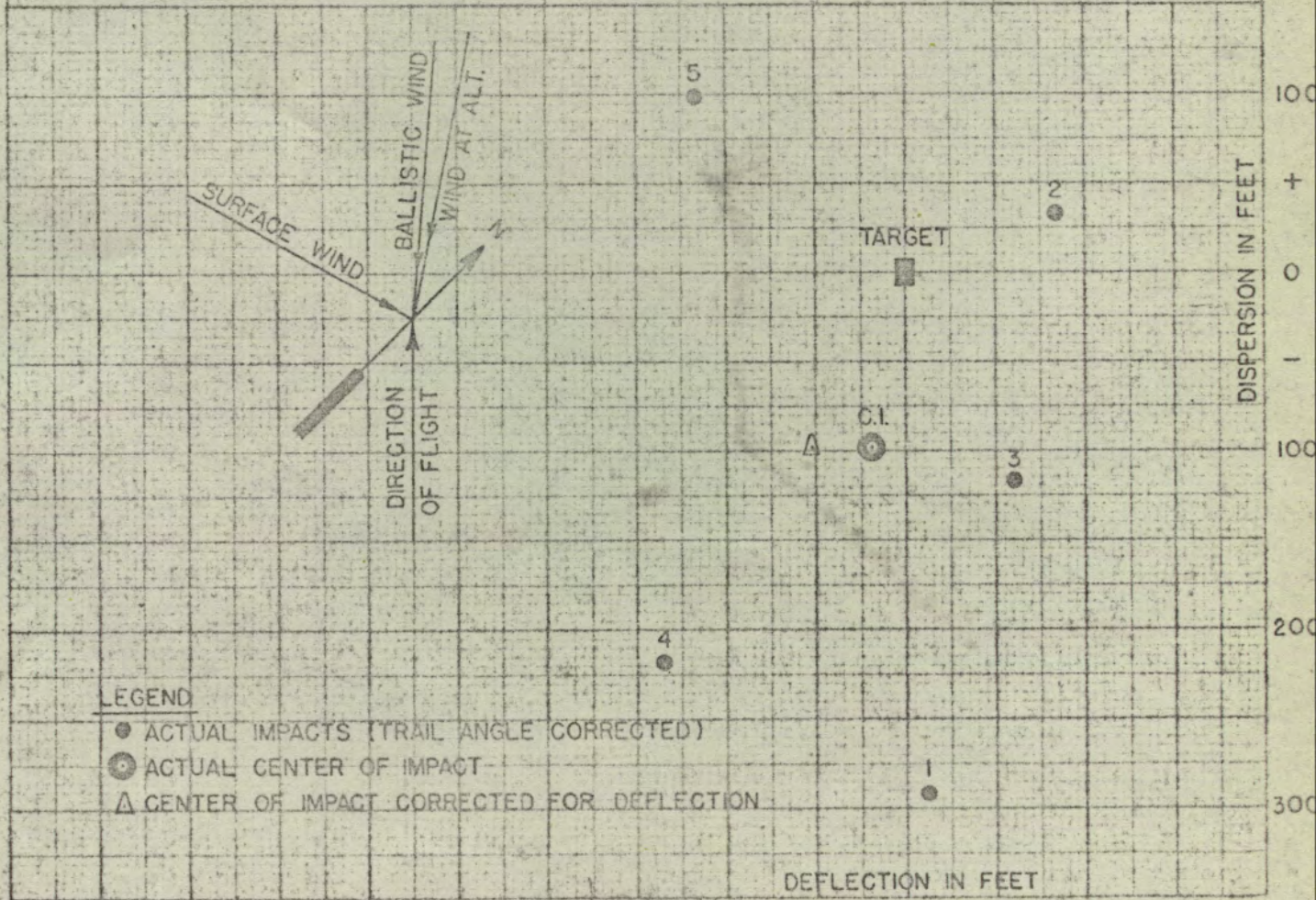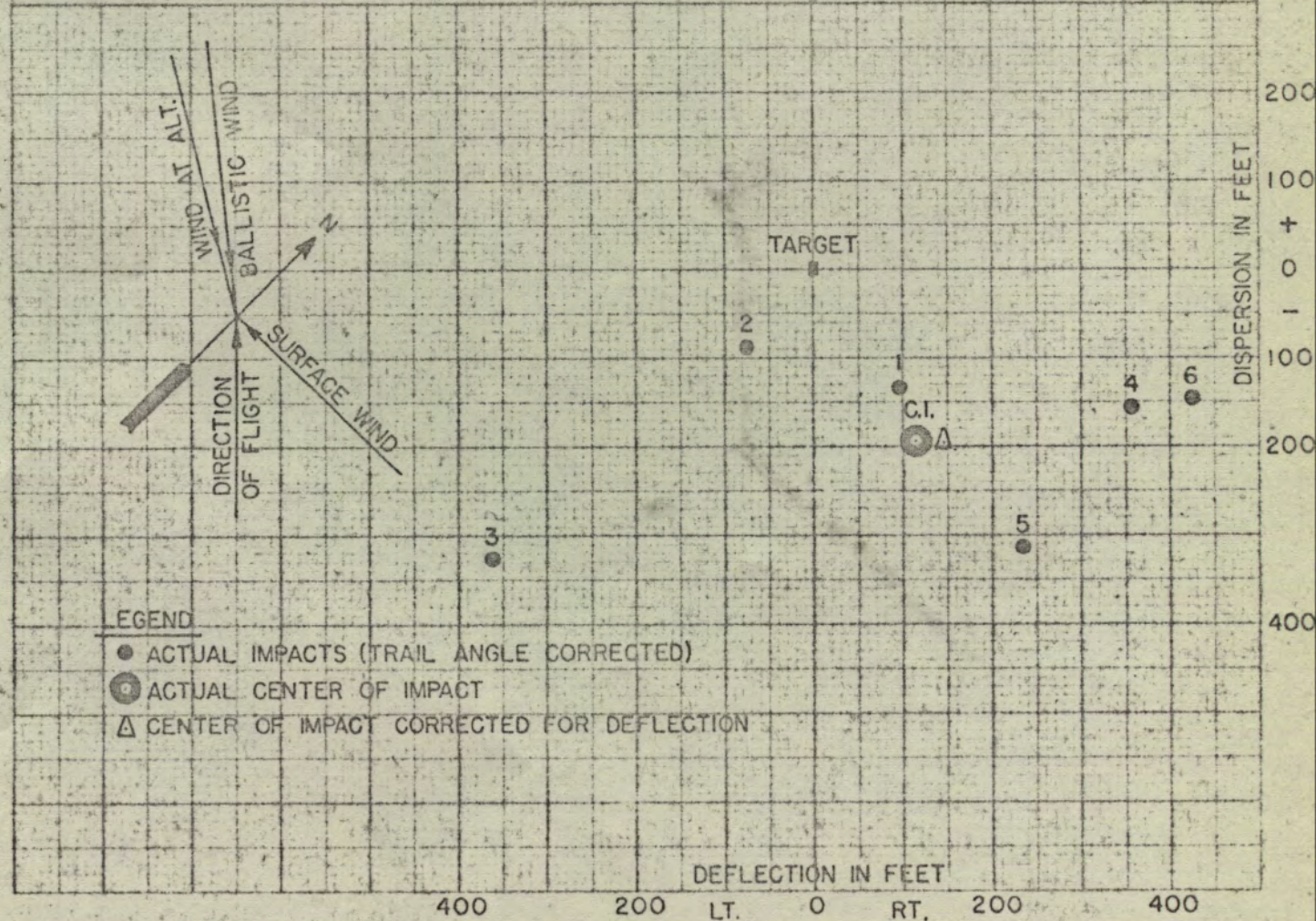PILOT: W. O. J. A. LEE   BOMBARDIER: CAPT. C. S. THORPE

SKY   AIR: TRAIL AND D.S. BASED ON C = 1.60

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND. OBS. FT.	AIR SPEED CAL. IND. M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GR'ND. OBS. M/HR	GR'ND. SPEED GR'ND OBS. M/HR	CLIMB-GLIDE AIR OBS. FT/MIN.	CLIMB-GLIDE GR'ND. OBS. FT/MIN.	RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1	11:26	15690	15585	134	170.4	170.0	121.9		+190.8		291	12	
2	11:35	15730	15616	134	170.4	173.0	124.3		− 8.4	33		84	
3	11:50	15710	15607	135	171.7	174.3	124.8		+ 58.8		117	60	
4	11:58	15700	15566	136	172.9	175.8	126.1		+119.4		219		135
5	12:11	15720	15561	138	175.4	178.2	128.3		−236.4	99			117
6													

DIFFERENTIAL BALLISTIC WIND M/HR.   CENTER OF IMPACT   99   19

RANGE: −10.0   CROSS: −5.9   MEAN DEVIATION   132   85

TIME		9:50	12:45	CORRECTIONS USED		
WIND	SURFACE, VELOCITY (M/HR)	7.0	14.0	MILS IN	RANGE	DEFL.
	AT ALTITUDE, VELOCITY "	48.3	51.3			
	BALLISTIC VELOCITY "	37.5	37.9	WIND	−4.7	2.3 L
	BALLISTIC AZIMUTH (TO)	321.0°	319.2°			
DENSITY	AT SURFACE	0.993	0.985	DENSITY	−0.2	—
	BALLISTIC (SURFACE)	1.006	1.002			
	BALLISTIC (AIR OBS.)	0.970	0.967	TOTAL	−4.9	2.3 L

LEGEND
- ● ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)
- ◉ ACTUAL CENTER OF IMPACT
- △ CENTER OF IMPACT CORRECTED FOR DEFLECTION

DEFLECTION IN FEET
100   LT.   O   RT.   100

DISPERSION IN FEET

RESULTS OF RANGE BOMBING NO. 8

MAY 3, 1938   100 LB. PRACTICE BOMB M38A2   AIRPLANE B18

PILOT: W. O. J. A. LEE   BOMBARDIER: SGT. S. C. SMINK

SKY: AIR: TRAIL AND D.S. BASED ON C = 1.60

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND OBS. FT.	AIR SPEED CAL IND. M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GRND. OBS. M/HR	GRND. SPEED GR'ND OBS. M/HR	CLIMB-GLIDE AIR OBS. FT/MIN	CLIMB-GLIDE GR'ND. OBS. FT/MIN	DEVIATIONS RANGE OVER FT.	DEVIATIONS RANGE SHORT FT.	DEVIATIONS DEFLECTION RIGHT FT.	DEVIATIONS DEFLECTION LEFT FT.
1	11:15	15690	15655	133	169.3	172.3	130.2		− 24.0		132	96	
2	11:23	15700	15655	135	171.9	170.2	128.0		−252.6		87		75
3	11:32	15650	15598	133	169.2	173.6	131.5		−162.6		327		360
4	11:41	15730	15688	136	173.3	170.4	128.3		− 22.8		156	357	
5	11:48	15700	15634	135	171.9	173.4	131.0		− 61.8		312	237	
6	11:55	15730	15661	135	171.9	174.1	132.1		− 64.2		147	426	

DIFFERENTIAL BALLISTIC WIND M/HR.   CENTER OF IMPACT   194 | 114

RANGE: −5.1   CROSS: +5.6   MEAN DEVIATION   84 | 227

TIME		9:56	2:08	CORRECTIONS USED		
WIND	SURFACE, VELOCITY (M/HR)	9.0	5.0	MILS IN	RANGE	DEFL.
	AT ALTITUDE, VELOCITY "	38.3	45.3			
	BALLISTIC VELOCITY "	32.2	38.9	WIND	−2.4	2.1 R
	BALLISTIC AZIMUTH (TO)	309.1°	306.9°			
DENSITY	AT SURFACE	0.991	0.978	DENSITY	−0.3	—
	BALLISTIC (SURFACE)	1.005	0.998	TOTAL	−2.7	2.1 R
	BALLISTIC (AIR OBS.)	0.967	0.965			

LEGEND
- ● ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)
- ◉ ACTUAL CENTER OF IMPACT
- △ CENTER OF IMPACT CORRECTED FOR DEFLECTION

DEFLECTION IN FEET

400   200   LT.   0   RT.   200   400

RESULTS OF RANGE BOMBING NO. 9

MAY 6, 1938   100 LB. PRACTICE BOMB M38A2   AIRPLANE B18
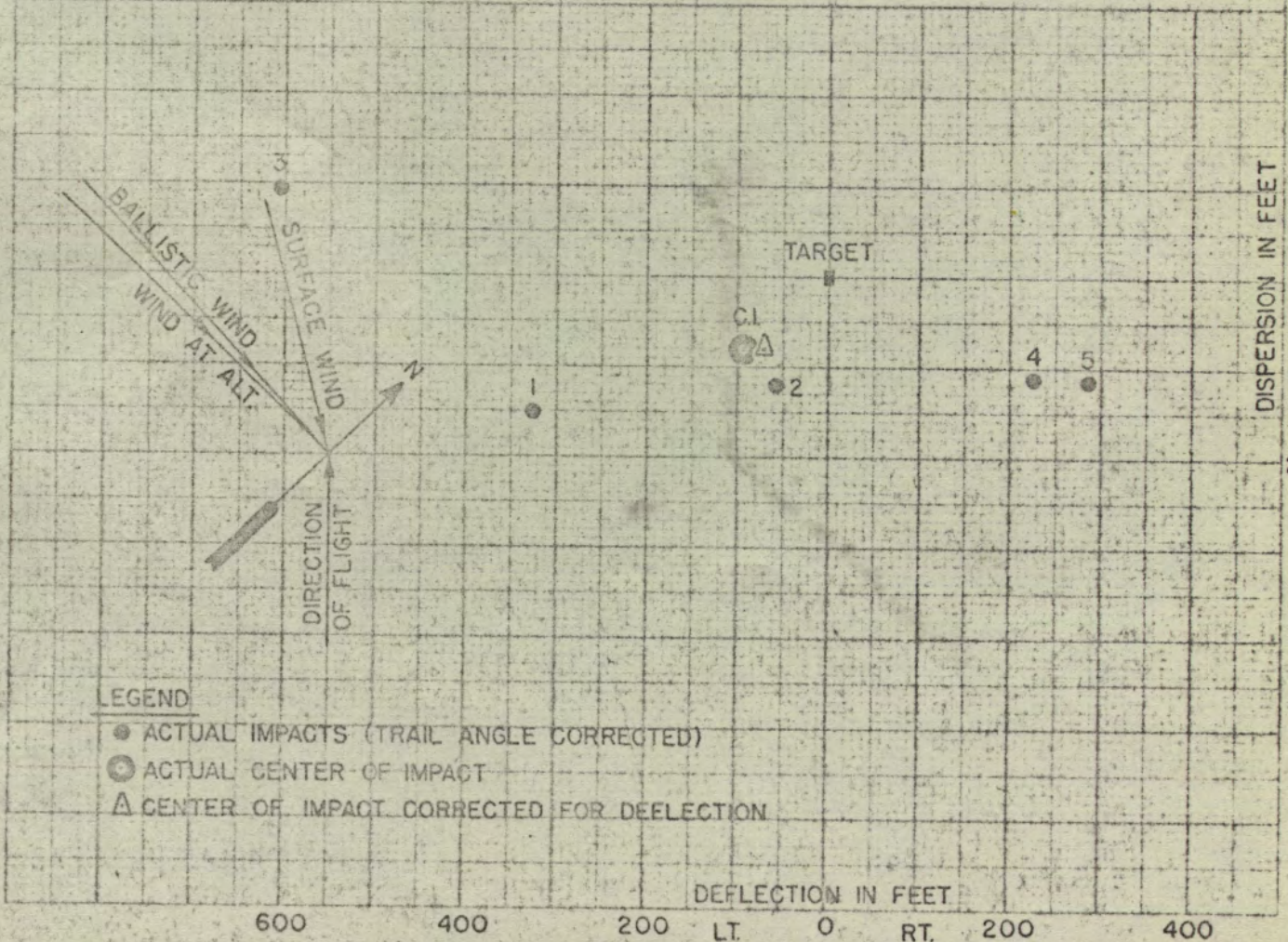
PILOT: W. O. J. A. LEE   BOMBARDIER: SGT. S. C. SMINK

SKY: AIR: TRAIL AND D.S. BASED ON C = 1.60

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GRND. OBS. FT.	AIR SPEED CAL. IND. M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GRND. OBS. M/HR	GRND. SPEED GRND. OBS. M/HR	CLIMB-GLIDE AIR OBS. FT/MIN	CLIMB-GLIDE GRND. OBS. FT/MIN	DEVIATIONS FROM TARGET RANGE OVER FT.	DEVIATIONS FROM TARGET RANGE SHORT FT.	DEVIATIONS FROM TARGET DEFLECTION RIGHT FT.	DEVIATIONS FROM TARGET DEFLECTION LEFT FT.
1	11:45	12570	12523	134	162.1	160.6	134.4		− 1.8		150		321
2	11:58	12520	12497	132	159.7	154.0	123.4		+ 2.4		120		57
3	12:06	12570	12556	133	161.1	155.4	121.1		+ 44.4	93			603
4	12:14	12540	12508	134	162.1	157.5	126.0		−105.0		111	228	
5	12:25	12520	12489	135	163.4	163.8	133.2		+ 44.4		111	288	
6													

DIFFERENTIAL BALLISTIC WIND M/HR.   CENTER OF IMPACT   80   93

RANGE: −1.7   CROSS: +5.1   MEAN DEVIATION   69   295

	TIME	9:53	1:04	CORRECTIONS USED		
WIND	SURFACE, VELOCITY (M/HR)	17.0	14.0	MILS IN	RANGE	DEFL.
WIND	AT ALTITUDE, VELOCITY "	35.8	40.4			
WIND	BALLISTIC VELOCITY "	31.0	34.1	WIND	−0.8	1.9 R
WIND	BALLISTIC AZIMUTH (TO)	272.0°	284.6°			
DENSITY	AT SURFACE	0.968	0.968	DENSITY	−1.6	—
DENSITY	BALLISTIC (SURFACE)	0.989	0.989			
DENSITY	BALLISTIC (AIR OBS.)	0.963	0.968	TOTAL	−2.4	1.9 R

LEGEND
- ● ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)
- ◎ ACTUAL CENTER OF IMPACT
- △ CENTER OF IMPACT CORRECTED FOR DEFLECTION

DISPERSION IN FEET

DEFLECTION IN FEET

600   400   200   LT.   0   RT.   200   400

RESULTS OF RANGE BOMBING NO. 12

MAY 25, 1938   100 LB. PRACTICE BOMB M38A2   AIRPLANE B18

PILOT: W. O. J. A. LEE   BOMBARDIER: CAPT. C. S. THORPE
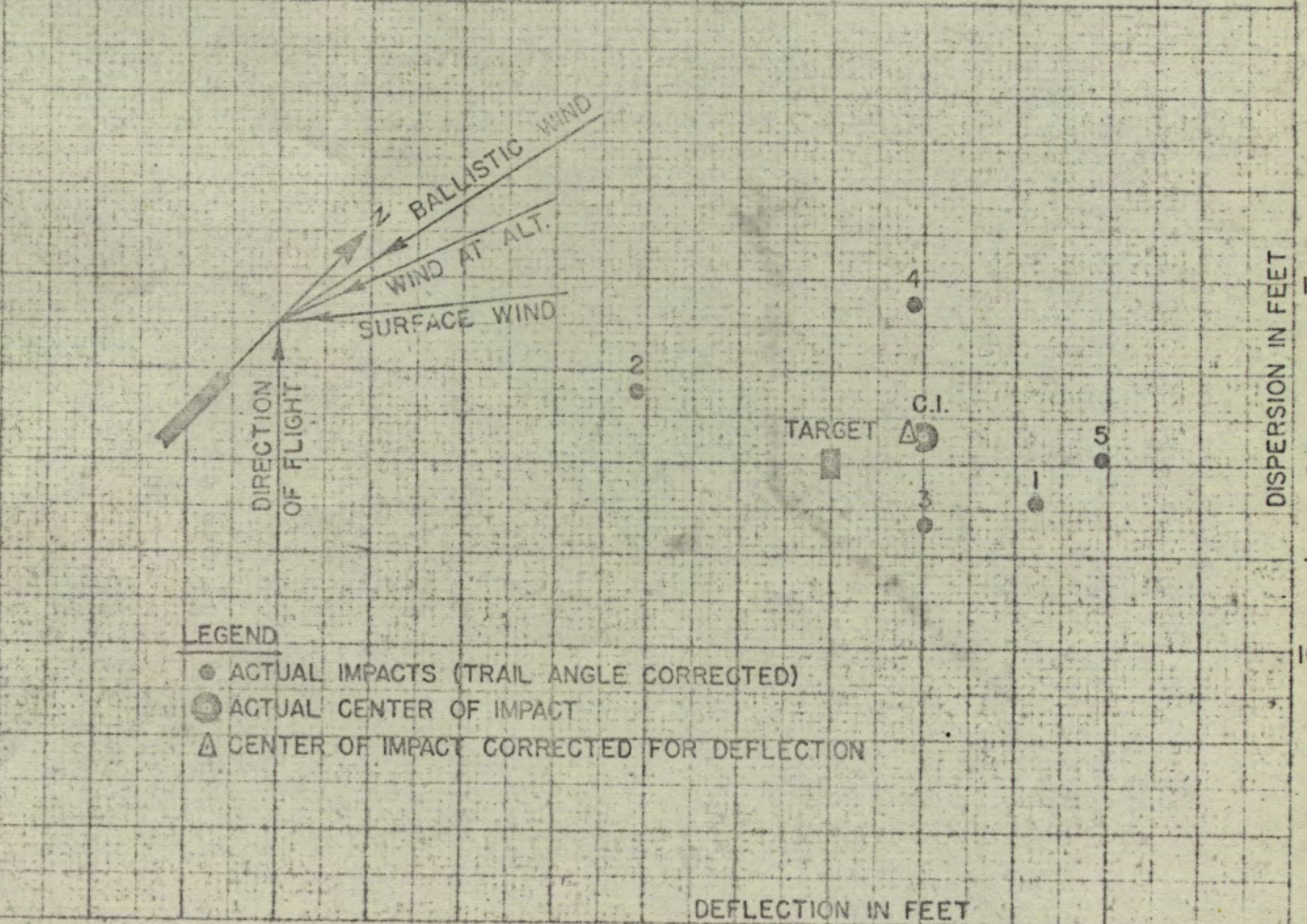
SKY: AIR: TRAIL AND D.S. BASED ON C = 1.60

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND. OBS. FT.	AIR SPEED CAL. IND. M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GR'ND OBS. M/HR	GRND. SPEED GR'ND OBS. M/HR	CLIMB-GLIDE AIR OBS. FT/MIN	CLIMB-GLIDE GR'ND OBS. FT/MIN	RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1	11:36	6180	6176	143	157.2	155.4	155.7		+ 25.8		21	111	
2	11:50	6160	6156	141	154.8	151.5	151.6		+ 6.0	39			105
3	12:02	6160	6167	141	154.8	154.2	154.5		+37.8		33	51	
4	12:10	6150	6130	142	155.9	155.0	155.7		- 1.2	87		45	
5	12:15	6110	6057	143	156.7	157.4	158.0		+124.8	3		147	
6													

DIFFERENTIAL BALLISTIC WIND M/HR.		CENTER OF IMPACT	15		50	
RANGE: -1.5	CROSS: -3.8	MEAN DEVIATION		38		64

	TIME	10:32	12:39	CORRECTIONS USED		
WIND	SURFACE, VELOCITY (M/HR)	8.0	6.0	MILS IN	RANGE	DEFL.
	AT ALTITUDE, VELOCITY	5.5	3.8			
	BALLISTIC VELOCITY "	1.5	1.1	WIND	- 0.7	1.4 LT.
	BALLISTIC AZIMUTH (TO)	12.7°	179.4°			
DENSITY	AT SURFACE	1.001	0.992	DENSITY	+2.4	—
	BALLISTIC (SURFACE)	1.006	0.999			
	BALLISTIC (AIR OBS.)	1.021	1.016	TOTAL	+1.7	1.4 LT.

LEGEND
⊙ ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)
◯ ACTUAL CENTER OF IMPACT
△ CENTER OF IMPACT CORRECTED FOR DEFLECTION

DIRECTION OF FLIGHT

BALLISTIC WIND
WIND AT ALT.
SURFACE WIND

DISPERSION IN FEET

DEFLECTION IN FEET
100   LT.   0   RT.   100

RESULTS OF RANGE BOMBING NO. 37

OCT. 31, 1938   100 LB. PRACTICE BOMB — M38 A2   AIRPLANE B-18
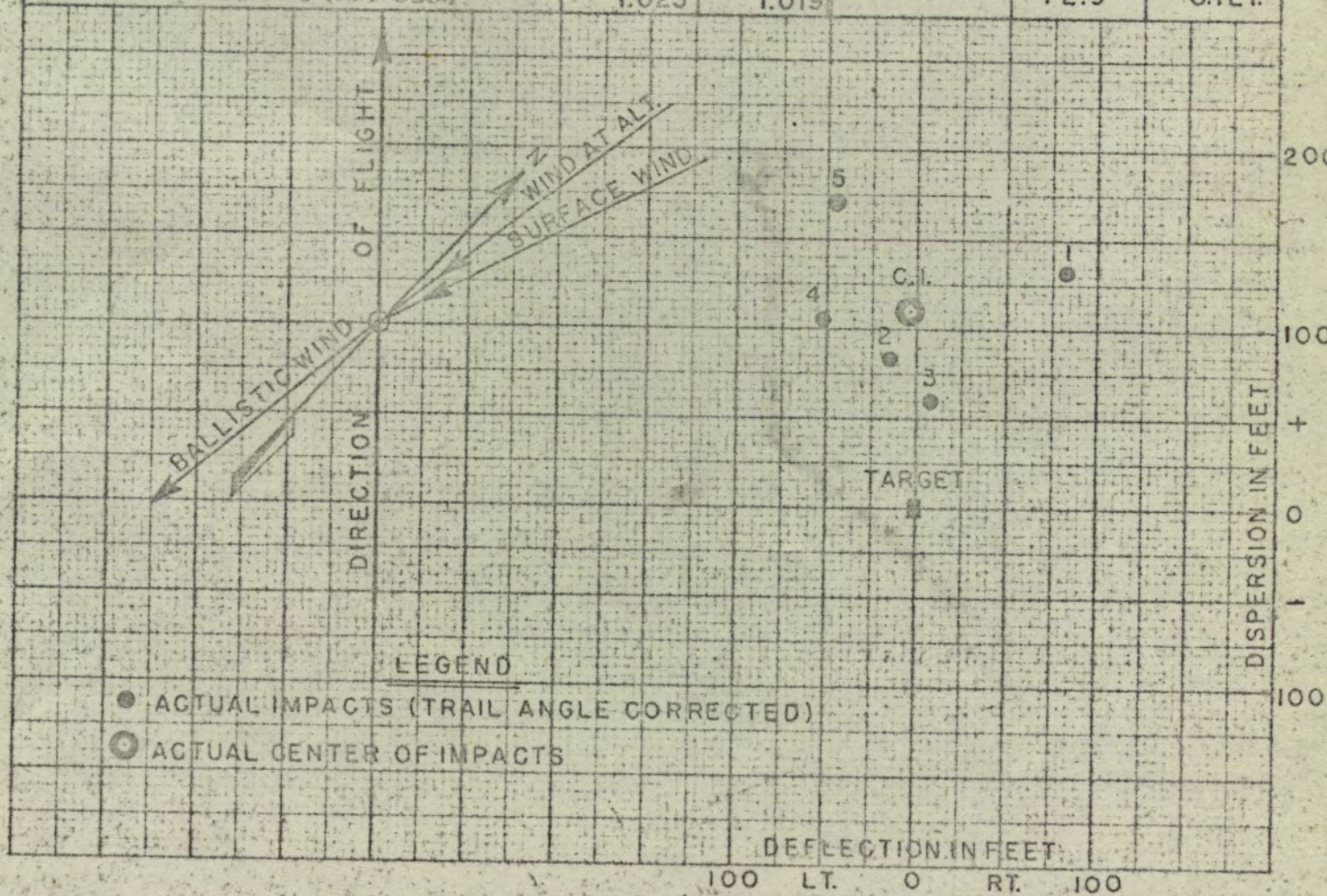PILOT: CAPT. D.W. WATKINS   BOMBARDIER: CAPT. C.S. THORPE
SKY: AIR: TRAIL AND D.S. BASED ON C = 2.019

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND OBS. FT.	AIR SPEED CAL. IND. M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GR'ND OBS. M/HR	GR'ND SPEED GR'ND OBS. M/HR	CLIMB OR GLIDE GR'ND OBS. FT/MIN	HOR. RANGE FT.	RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1	10:37	7080	7058	166	185.6	184.5	171.8	−73.2	4959	132		84	
2	10:45	7090	7069	164	183.4	180.9	168.5	+148.2	4879	84			15
3	10:58	7100	7074	165	184.5	180.3	167.3	−32.5	4865	60		9	
4	11:07	7040	7035	166	185.5	182.8	171.9	+35.8	4978	105			51
5	11:20	7100	7060	165	184.5	180.8	168.0	+825	4889	171			45
6													
CENTER OF IMPACT										110			4
MEAN DEVIATION										33		40	

	TIME	9:22 A.M.	12:52 P.M.	CORRECTIONS USED		
WIND VELOCITY M.P.H.	SURFACE	15.0	7.0	MILS IN	RANGE	DEFL.
	AT ALTITUDE	20.3	16.8			
	BALLISTIC	20.7	16.3	WIND	+0.4	0.1 LT.
	DIFFERENTIAL BALLISTIC RANGE	+1.0	−0.6			
	CROSS	−0.3	−0.1	DENSITY	+2.5	—
DENSITY	AT SURFACE	1.050	1.031			
	BALLISTIC (SURFACE)	1.044	1.029	TOTAL	+2.9	0.1 LT.
	BALLISTIC (AIR OBS.)	1.023	1.019			

LEGEND

● ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)

◎ ACTUAL CENTER OF IMPACTS

DIRECTION OF FLIGHT

WIND AT ALT.
SURFACE WIND
BALLISTIC WIND

TARGET   C.I.

DISPERSION IN FEET

DEFLECTION IN FEET   100 LT.   0   RT.   100

28

RESULTS OF RANGE BOMBING NO. 38

OCT. 31, 1938   100 LB. PRACTICE BOMB — M38A2   AIRPLANE B-4A

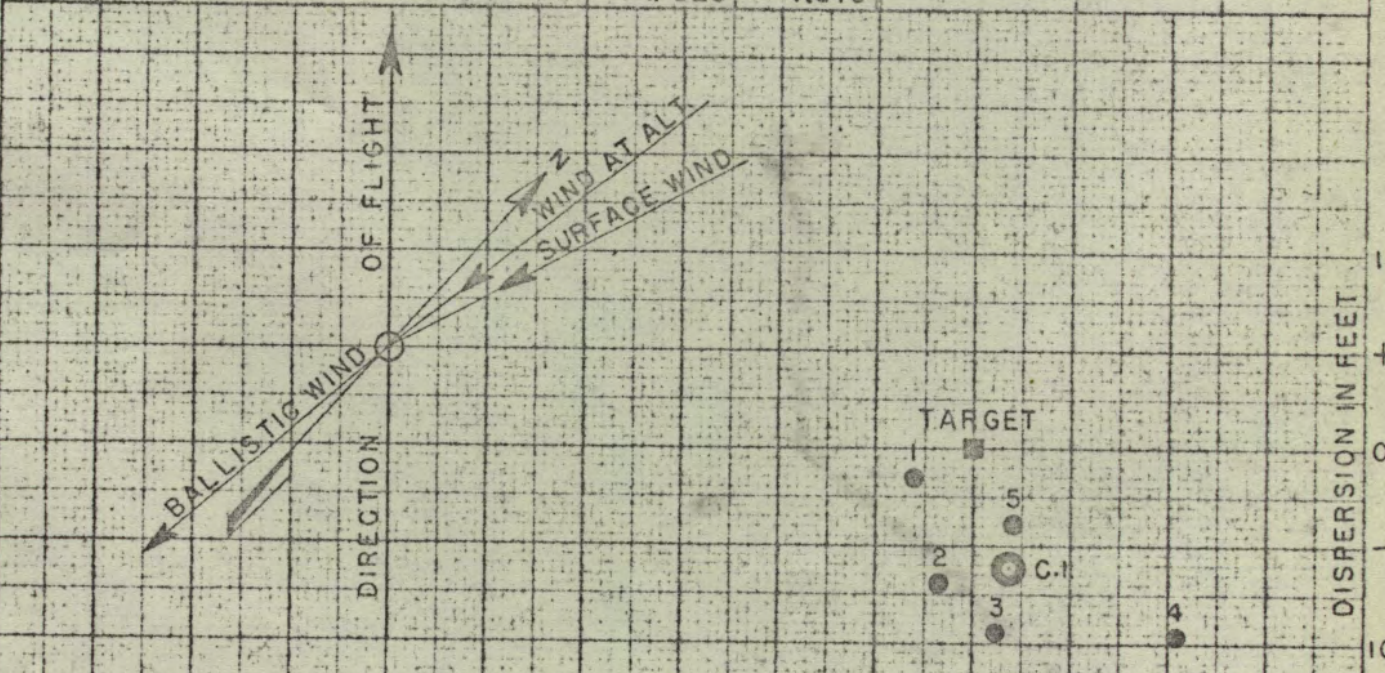PILOT: W.O. J.A. LEE   BOMBARDIER: SGT. S.C. SMINK

SKY: AIR: TRAIL AND D.S. BASED ON C = 2.019

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND OBS. FT.	AIR SPEED IND. M/HR.	AIR SPEED TRUE AIR OBS. M/HR.	AIR SPEED TRUE GR'ND OBS. M/HR.	GR'ND SPEED GR'ND OBS. M/HR.	CLIMB OR GLIDE GR'ND OBS. FT/MIN.	HOR. RANGE FT.	RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1	10:53	7120	6970	79	88.2	88.5	74.7	+ 87.7	2183		15		30
2	11:03	7200	6989	82	91.6	90.5	76.6	+ 46.8	2258		69		18
3	11:18	7180	6926	78	87.0	88.6	76.0	- 37.9	2230		93	12	
4	11:26	7120	6922	80	89.2	87.4	73.5	-271.8	2197		96	105	
5	11:33	7080	6907	82	91.5	90.2	77.4	0	2259		39	21	
6													
CENTER OF IMPACT											62	18	
MEAN DEVIATION											28	36	

TIME			9:22 A.M.	12:52 P.M.	CORRECTIONS USED		
WIND VELOCITY M.P.H.	SURFACE		15.0	7.0	MILS IN	RANGE	DEFL.
	AT ALTITUDE		20.3	16.8			
	BALLISTIC		20.7	16.0			
	DIFFERENTIAL BALLISTIC	RANGE	+1.0	-0.7	WIND	+0.3	0.1 LT.
		CROSS	-0.3	-0.4			
DENSITY	AT SURFACE		1.050	1.031	DENSITY	+2.5	—
	BALLISTIC (SURFACE)		1.044	1.029			
	BALLISTIC (AIR OBS.)		1.023	1.019	TOTAL	+2.8	0.1 LT.

LEGEND

● ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)

◉ ACTUAL CENTER OF IMPACTS

DEFLECTION IN FEET

100 LT.   0   RT. 100

RESULTS OF RANGE BOMBING NO. 45

NOV. 10, 1938   100 LB. PRACTICE BOMB — M38A2   AIRPLANE B-18
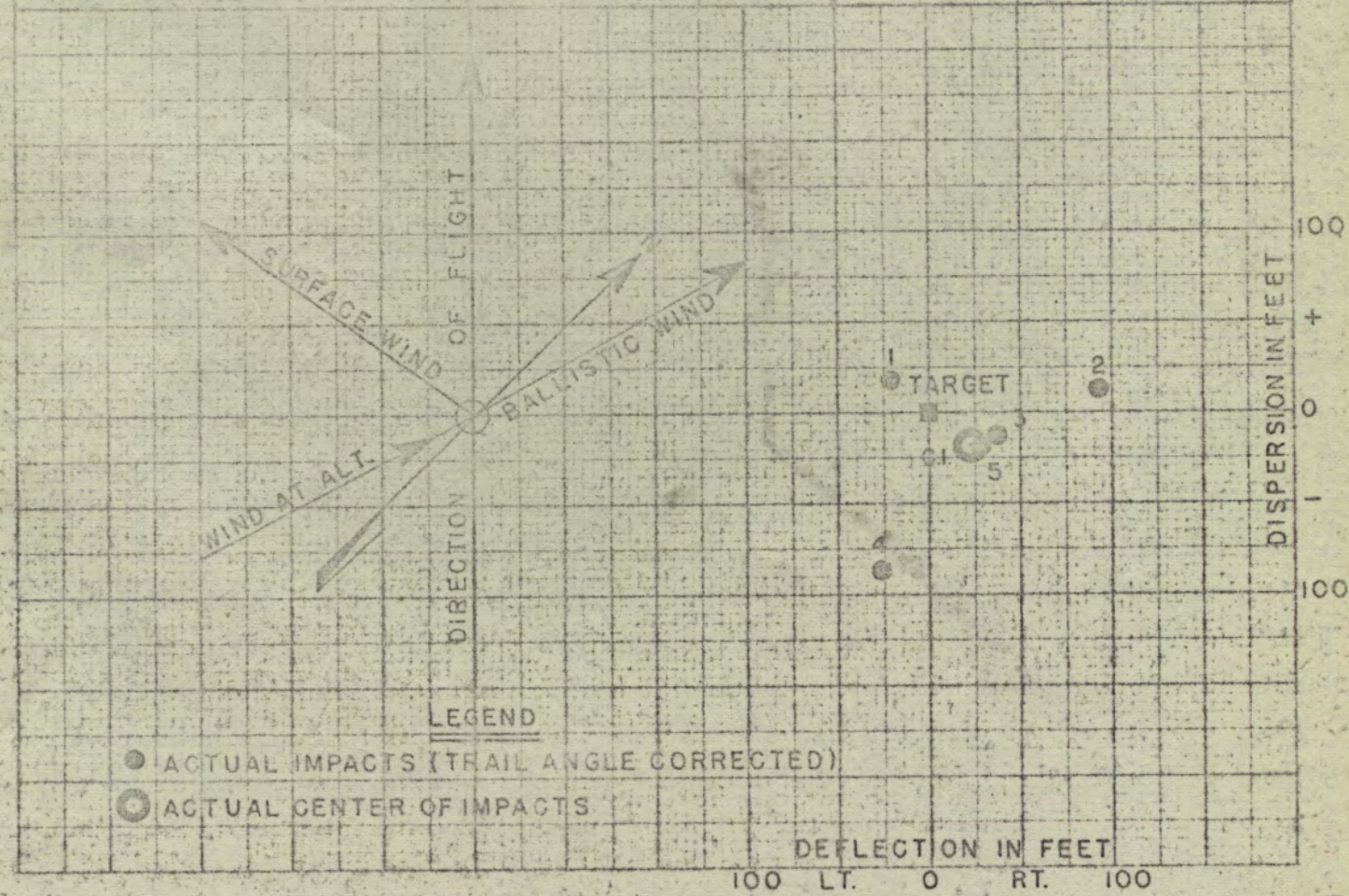
PILOT: CAPT. D.W. WATKINS   BOMBARDIER: CAPT. C.S. THORPE

SKY: AIR: TRAIL AND D.S. BASED ON C = 2.019

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND OBS. FT.	AIR SPEED CAL. IND. M/HR.	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GR'ND OBS. M/HR	GR'ND SPEED GR'ND OBS. M/HR.	CLIMB OR GLIDE GR'ND OBS. FT/MIN	HOR. RANGE FT.	DEV. RANGE OVER FT.	DEV. RANGE SHORT FT.	DEV. DEFLECTION RIGHT FT.	DEV. DEFLECTION LEFT FT.
1	11:21	7140	7138	165	184.7	181.2	186.0	+233.3	5524	18			21
2	11:29	7120	7112	164	183.5	181.6	186.8	+ 15.7	5479	12		93	
3	11:46	7140	7137	165	184.7	182.9	187.1	- 20.0	5512		12	36	
4	11:53	7140	7134	165	184.7	183.5	187.3	+ 74.6	5490		87		27
5	12:00	7140	7136	165	184.7	182.6	187.0	+150.0	5511		18	27	
6													
						CENTER OF IMPACT				17		22	
						MEAN DEVIATION				28		36	

		TIME:	10:50	1:14	CORRECTIONS USED		
	SURFACE		5.0	5.0	MILS IN	RANGE	DEFL.
WIND VELOCITY M.P.H.	AT ALTITUDE		16.4	23.7			
	BALLISTIC		14.0	19.9	WIND	+0.4	0.7 RT.
	DIFFERENTIAL (RANGE		+1.1	-0.1			
	BALLISTIC (CROSS		+2.1	+3.9	DENSITY	+2.2	———
	AT SURFACE		1.044	1.030			
DENSITY	BALLISTIC (SURFACE)		1.039	1.025	TOTAL	+2.6	0.7 RT.
			1.018	1.009			

LEGEND

● ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)

◎ ACTUAL CENTER OF IMPACTS

DEFLECTION IN FEET

100 LT.   0   RT.   100

30

RESULTS OF RANGE BOMBING NO. 46

NOV. 10, 1938 **100 LB. PRACTICE BOMB — M38A2** **AIRPLANE B-4A**
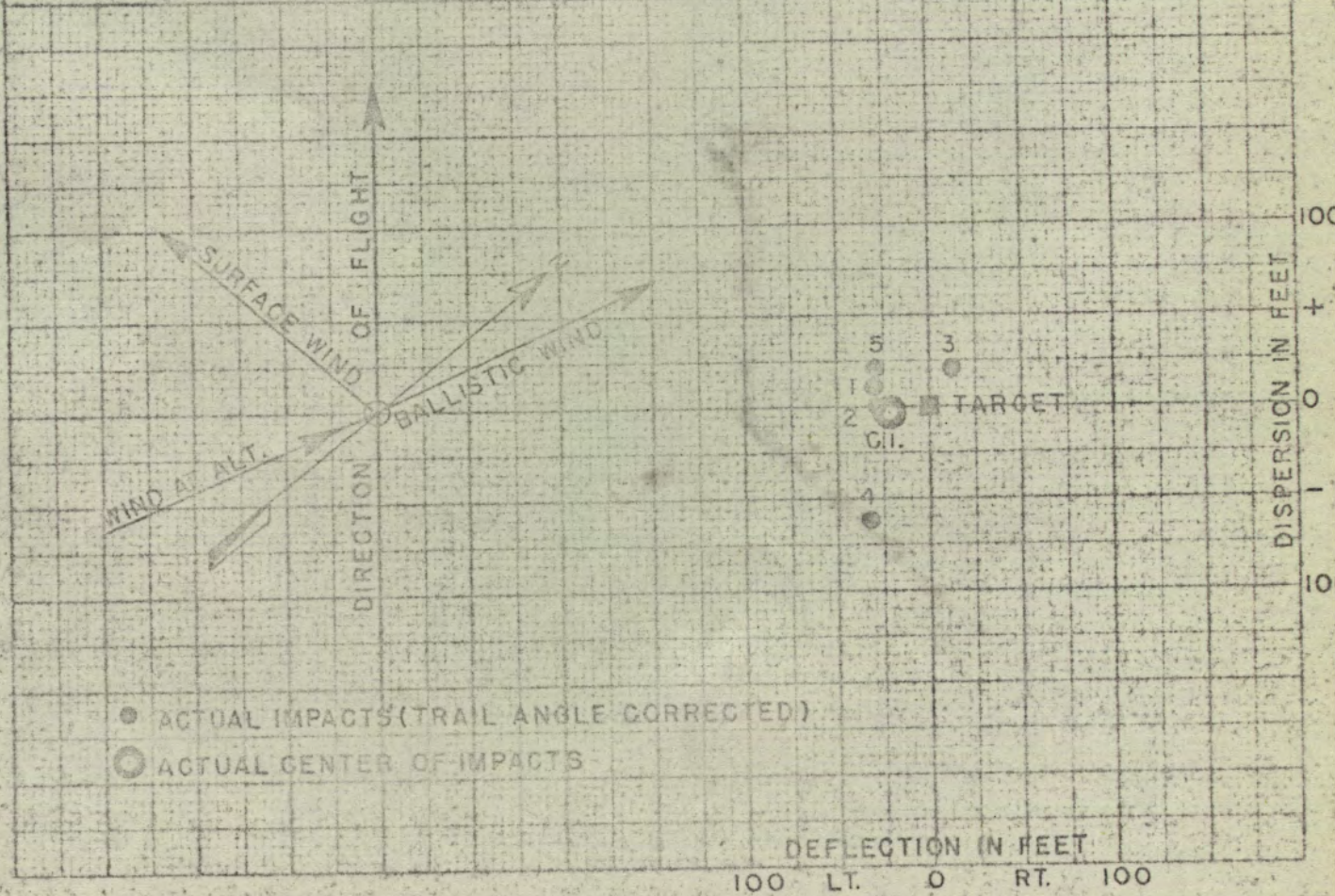
PILOT: W.O. J.A. LEE **BOMBARDIER SGT. S.C. SMINK**

SKY **AIR** **TRAIL AND D.S. BASED ON C # 2.019**

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND OBS. FT.	AIR SPEED IND. M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GR'ND OBS. M/HR	GR'ND SPEED GR'ND OBS. M/HR	CLIMB OR GLIDE GR'ND OBS. FT/MIN	HOR. RANGE FT.	RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1	11:25	7130	7144	85	95.1	95.0	96.4	+ 38.4	2885	12			30
2	11:32	7130	7092	85	95.1	95.6	98.0	+ 15.8	2886	0	0		27
3	11:38	7130	7138	85	95.1	97.2	99.7	+ 32.2	2967	21		12	
4	11:49	7130	7133	85	95.1	94.2	96.5	+ 78.4	2873		63		33
5	11:56	7130	7086	85	95.1	98.5	100.8	+ 5.2	2993	21			27
6													
								CENTER OF IMPACT				2	21
								MEAN DEVIATION		25		13	

		TIME	10:50	1:14	CORRECTIONS USED		
WIND VELOCITY M.P.H.	SURFACE		5.0	5.0	MILS IN	RANGE	DEFL.
	AT ALTITUDE		16.4	23.7			
	BALLISTIC		13.3	18.5	WIND	+ 0.3	0.7 RT.
	DIFFERENTIAL RANGE		+1.3	−0.4			
	BALLISTIC CROSS		+2.8	+5.3	DENSITY	+ 2.2	—
DENSITY	AT SURFACE		1.044	1.030			
	BALLISTIC (SURFACE)		1.039	1.025	TOTAL	+ 2.5	0.7 RT.
	BALLISTIC (AIR OBS.)		1.016	1.008			

● ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)

◯ ACTUAL CENTER OF IMPACTS

DEFLECTION IN FEET

100 LT.   0   RT.   100

DISPERSION IN FEET

RESULTS OF RANGE BOMBING NO. 49

JULY 11, 1939   100 LB. PRACTICE BOMB M38A2   AIRPLANE B18A

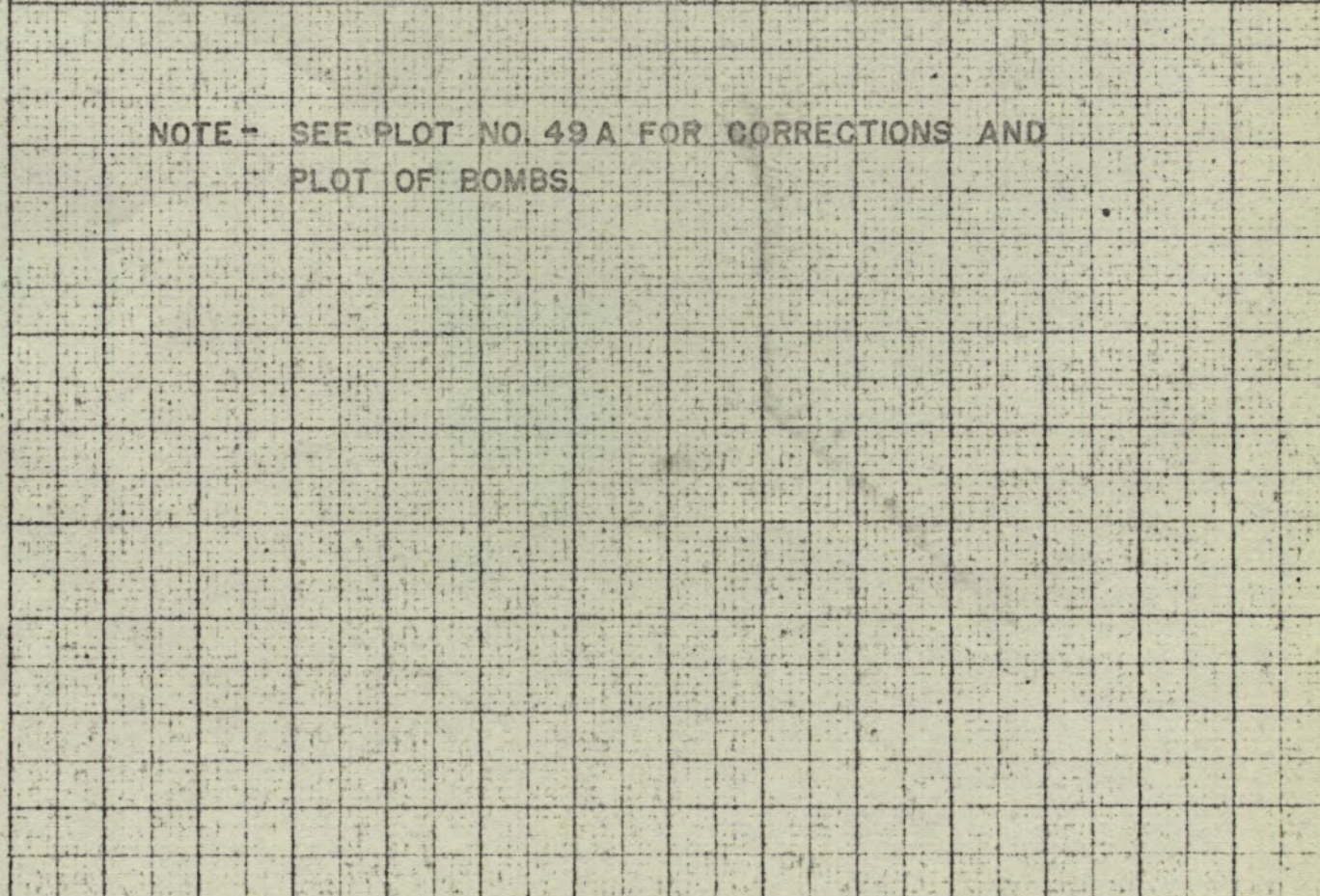PILOT: CAPT. D.W. WATKINS   BOMBARDIER: CAPT. C.S. THORPE

SKY: AIR: TRAIL AND D.S. BASED ON C = 1.21

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GR'ND SPEED GR'ND OBS. M/HR.	CLIMB OR GLIDE GR'ND OBS. FT/MIN.	HOR. RANGE FT.	DEVIATIONS FROM TARGET			
		AIR OBS. FT.	GR'ND. OBS. FT.	CAL. IND. M/HR.	TRUE					RANGE		DEFLECTION	
					AIR OBS. M/HR.	GR'ND. OBS. M/HR.				OVER FT.	SHORT FT.	RIGHT FT.	LEFT FT.
1	10:38	19850	19496	125	170.1	161.9	121.8	+124.1	5538	543		42	
2	10:48	19850	19452	124	168.5	162.1	126.5	+148.5	5774	384		57	
3	10:57	19850	19547	125	171.1	165.2	131.0	− 23.6	5996	153		177	
4	11:12	19850	19451	126	171.2	161.5	126.2	+114.1	5819	366			291
5	11:23	19870	19478	121	164.5	156.1	121.6	− 33.1	5530	201			300
6	11:32	19930	19414	126	171.1	164.5	131.2	− 74.5	6035	519		12	

CENTER OF IMPACT

MEAN DEVIATION

	TIME				CORRECTIONS USED		
WIND VELOCITY M.P.H.	SURFACE AT ALTITUDE BALLISTIC DIFFERENTIAL {RANGE BALLISTIC {CROSS				MILS IN	RANGE	DEFL.
					WIND		
DENSITY	AT SURFACE BALLISTIC (SURFACE) BALLISTIC (AIR OBS.)				DENSITY		
					TOTAL		

NOTE — SEE PLOT NO. 49 A FOR CORRECTIONS AND PLOT OF BOMBS.

RESULTS OF RANGE BOMBING NO. 49A.

JULY 11, 1939.   **100 LB. PRACTICE BOMB M.38A2**   AIRPLANE B18A

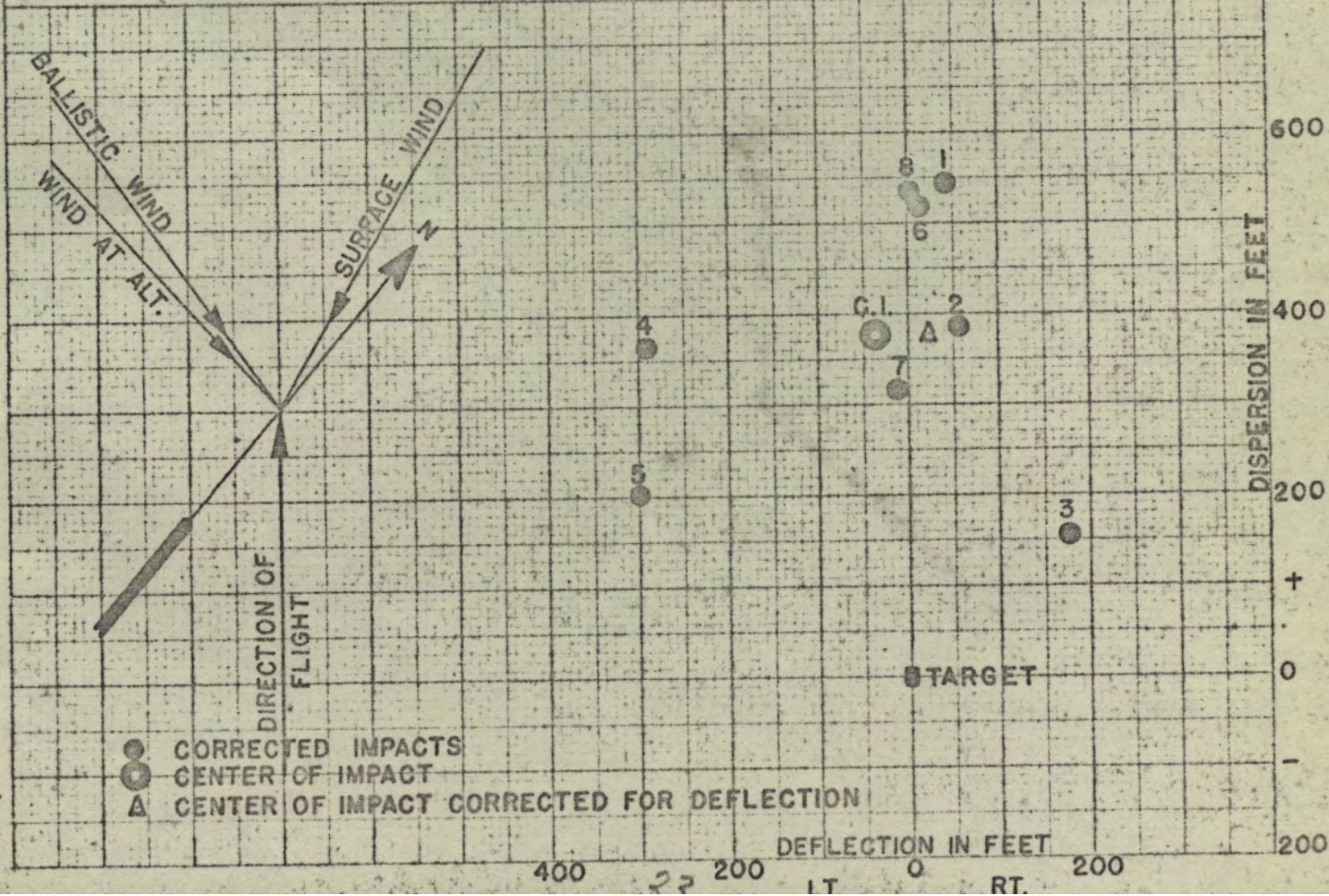PILOT: CAPT. D.W. WATKINS   BOMBARDIER: CAPT. C.S. THORPE

SKY: AIR: TRAIL AND D.S. BASED ON C=1.21

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND OBS. FT.	AIR SPEED CAL. IND. M/HR.	AIR SPEED TRUE AIR OBS. M/HR.	AIR SPEED TRUE GR'ND OBS. M/HR.	GR'ND SPEED GR'ND OBS. M/HR.	CLIMB OR GLIDE GR'ND OBS. FT/MIN.	HOR. RANGE FT.	RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
7	11:41	19850	19429	123	167.1	160.5	129.4	+32.9	5858	315			12
8	11:53	19850	19426	124	168.4	163.6	126.8	−36.3	5830	534		3	
3													
4													
5													
6													
CENTER OF IMPACT										377			39
MEAN DEVIATION										118			128

	TIME	9:54	12:36	CORRECTIONS USED		
WIND VELOCITY M.P.H.	SURFACE	11.0	9.0	MILS IN	RANGE	DEFL.
	AT ALTITUDE	39.3	47.7			
	BALLISTIC	32.8	34.3	WIND	−1.6	3.1 R
	DIFFERENTIAL {RANGE	−3.1	−12.3			
	BALLISTIC {CROSS	+7.0	+5.4	DENSITY	−0.2	—
DENSITY	AT SURFACE	0.996	0.988			
	BALLISTIC (SURFACE)	1.007	1.002	TOTAL	−1.8	3.1 R
	BALLISTIC (AIR OBS.)	0.954				

CORRECTED IMPACTS
CENTER OF IMPACT
CENTER OF IMPACT CORRECTED FOR DEFLECTION

DISPERSION IN FEET

DEFLECTION IN FEET

RESULTS OF RANGE BOMBING NO: 50

JULY 17, 1939. BOMBS NO. 1 & 2 100 LB. PRACTICE M38A2   AIRPLANE B18A
BOMBS NO. 3-7 100 LB. DEMOLITION M30   BOMBARDIER: SGT. S.C. SMINK
PILOT: CAPT. D.W. WATKINS & W.O. J.A. LEE

SKY: AIR: TRAIL AND D.S. BASED ON C=1.21

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND. OBS. FT.	AIR SPEED CAL. IND. M/HR.	AIR SPEED TRUE AIR OBS. M/HR.	AIR SPEED TRUE GR'ND. OBS. M/HR.	GR'ND SPEED GR'ND OBS. M/HR.	CLIMB OR GLIDE GR'ND OBS. FT/MIN.	HOR. RANGE FT.	RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1	10:35	19900	19574	121	164.8	160.0	122.4	+204.9	5642	267		303	
2	10:45	19900	19609	119	162.2	157.1	118.1	- 31.6	5350	282			384
3	10:53	19900	19564	120	163.4	161.0	122.0	- 97.7	5181		390	3	
4	11:00	19900	19556	123	167.5	166.0	125.5	- 59.0	5492	45			60
5	11:09	19900	19575	122	166.2	165.0	124.2	- 75.5	5504	87		327	
6	11:15	19900	19559	121	164.8	164.9	124.8	+ 65.9	5485	264		12	

CENTER OF IMPACT

MEAN DEVIATION

TIME				CORRECTIONS USED		
				MILS IN	RANGE	DEFL.
WIND VELOCITY M.P.H. { SURFACE AT ALTITUDE BALLISTIC DIFFERENTIAL {RANGE BALLISTIC {CROSS				WIND		
				DENSITY		
DENSITY {AT SURFACE BALLISTIC (SURFACE) BALLISTIC (AIR OBS.)				TOTAL		

NOTE- SEE PLOT NO. 50A FOR CORRECTIONS AND
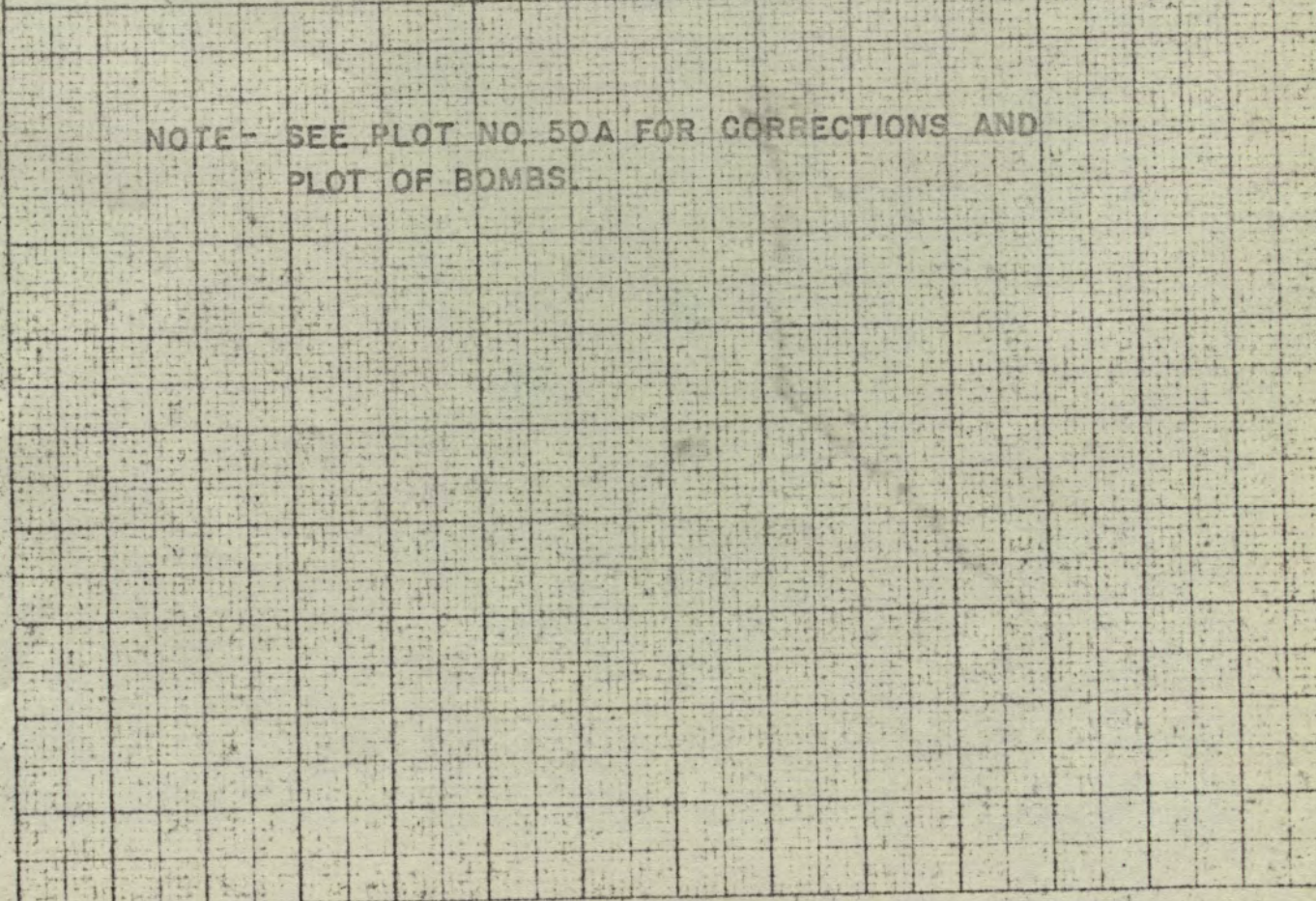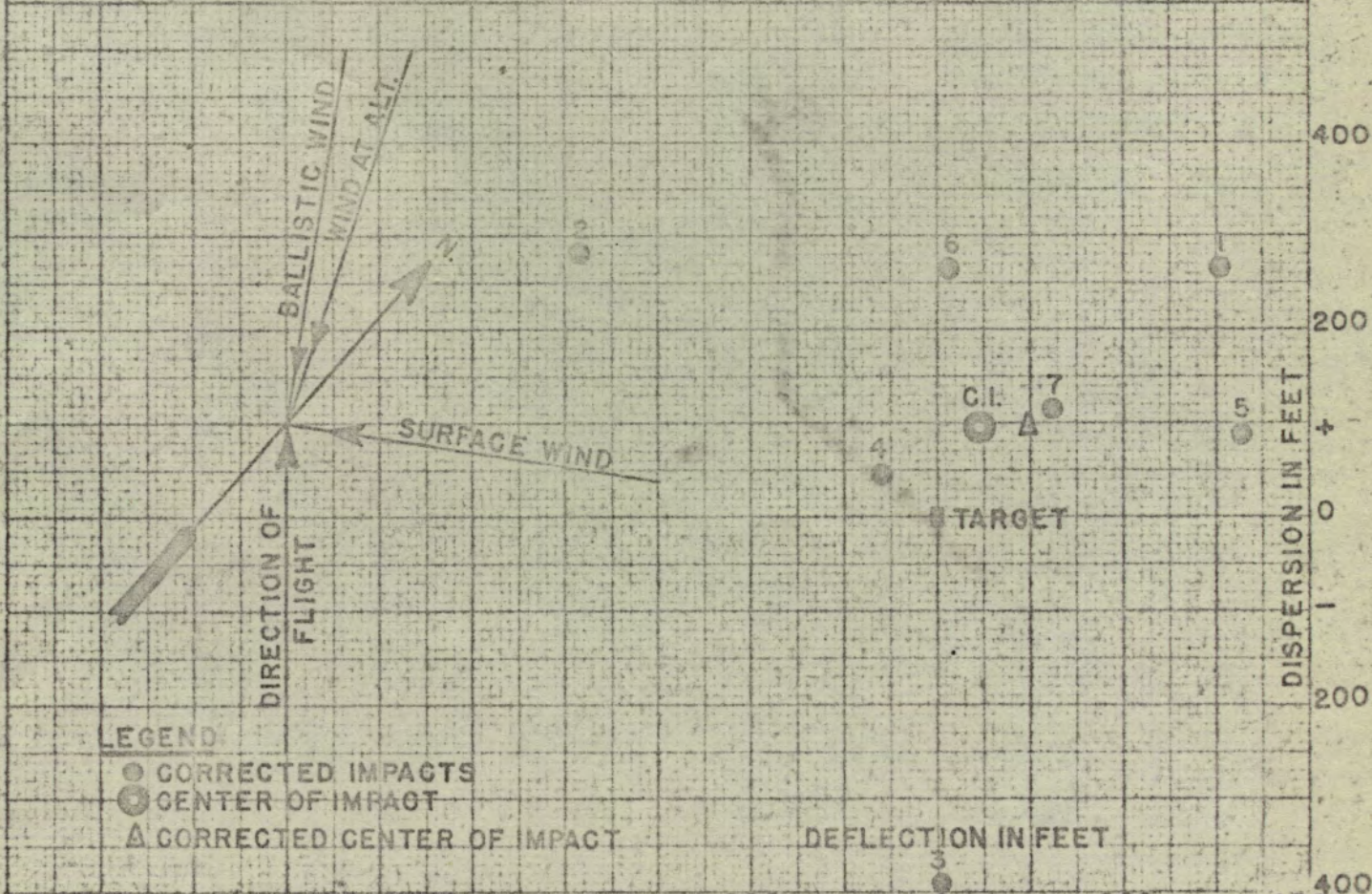PLOT OF BOMBS.

RESULTS OF RANGE BOMBING NO. 50A

JULY 17, 1939. BOMBS NO.1 & 2 100 LB. PRACTICE M38A2   AIRPLANE B18A
  BOMBS NO.3 - 7 100 LB. DEMOLITION M30
PILOT: CAPT. D.W. WATKINS & W.O. J.A. LEE   BOMBARDIER: SGT. S.C. SMINK
SKY: AIR: TRAIL AND D.S. BASED ON C # 1.21

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND. OBS. FT.	AIR SPEED CAL. IND. M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GR'ND. OBS. M/HR	GR'ND SPEED GR'ND OBS. M/HR	CLIMB OR GLIDE GR'ND OBS. FT/MIN	HOR. RANGE FT.	RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
7	11:28	19910	19575	123	167.6	165.1	125.5	+ 7.0	5585	114		123	
2													
3													
4													
5													
6													
CENTER OF IMPACT										96		46	
MEAN DEVIATION										156		175	

		TIME	10:00	11:55	CORRECTIONS USED		
					MILS IN	RANGE	DEFL.
WIND VELOCITY M.P.H.	SURFACE		4.0	6.0			
	AT ALTITUDE		38.7	42.0	WIND	- 3.1	2.6 L
	BALLISTIC		31.5	32.1			
	DIFFERENTIAL BALLISTIC RANGE		- 6.0	- 5.8			
	DIFFERENTIAL BALLISTIC CROSS		-10.2	+ 0.2	DENSITY	- 0.5	—
DENSITY	AT SURFACE		0.991	0.983			
	BALLISTIC (SURFACE)		1.005	1.001	TOTAL	- 3.6	2.6 L
	BALLISTIC (AIR OBS.)		0.948				

LEGEND
◉ CORRECTED IMPACTS
◉ CENTER OF IMPACT
△ CORRECTED CENTER OF IMPACT

DEFLECTION IN FEET

DISPERSION IN FEET

RESULTS OF RANGE BOMBING NO. 61

JUNE 21, 1940 **100 LB PRACTICE** **BOMB M38A2** **AIRPLANE B-17B**

PILOT : LT. B.A. SCHREIRER   BOMBARDIER : LT. M.F. SUMMERFELT

SKY : CLEAR   AIR : SMOOTH   TRAIL AND D.S. BASED ON BT-100-B-2

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS FT.	ALTITUDE GR'ND OBS FT.	AIR SPEED CAL IND M/HR	AIR SPEED TRUE AIR OBS M/HR	AIR SPEED TRUE GR'ND OBS M/HR	GR'ND SPEED GR'ND OBS M/HR	CLIMB OR GLIDE GR'ND OBS FT/MIN	HOR. RANGE FT.	RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1	6:29	25180	24264	160	234.7	224.7	178.5	-320.7	8720		366		828
2	6:37	25130	24346	158	232.1	217.5	171.7	-154.0	8347		456	201	
3		24990		158									
4	6:55	25210	24366	157	230.7	221.1	174.3	-152.6	8349	207			513
5	7:03	25250	24372	158	232.2	222.0	176.8	-420.3	8724		195	147	
6													
						CENTER OF IMPACT					203		248
						MEAN DEVIATION				209		422	

			R.O.S.	R.O.S.	CAMERA	
	TIME		5:30	7:23	7:03	
WIND VELOCITY M.P.H.	SURFACE			11.0	15.0	
	AT ALTITUDE			50.4		
	BALLISTIC RANGE WIND			-41.6		
	BALLISTIC CROSS WIND			18.5		
DENSITY	AT SURFACE		0.999		1.007	
	BALLISTIC (SURFACE)		1.011		1.013	
	BALLISTIC (AIR OBS.)		1.033			

LEGEND

● ACTUAL IMPACTS

○ ACTUAL CENTER OF IMPACT

DEFLECTION IN FEET

800   600   600   200 LT   0   RT   200

RESULTS OF RANGE BOMBING NO.65

JULY 5, 1940　　　　100 LB PRACTICE BOMB M38A2　　　　AIRPLANE B-17B

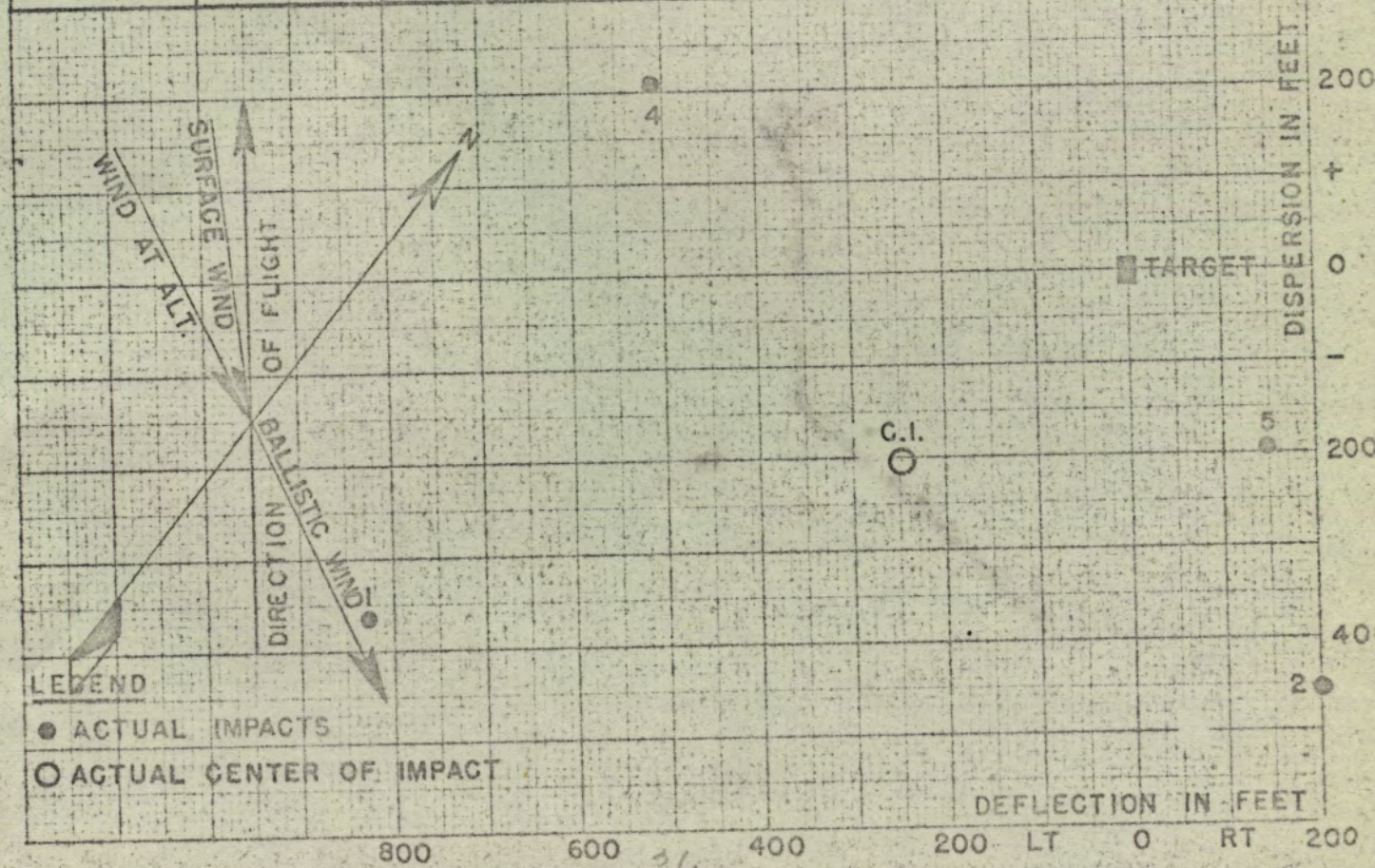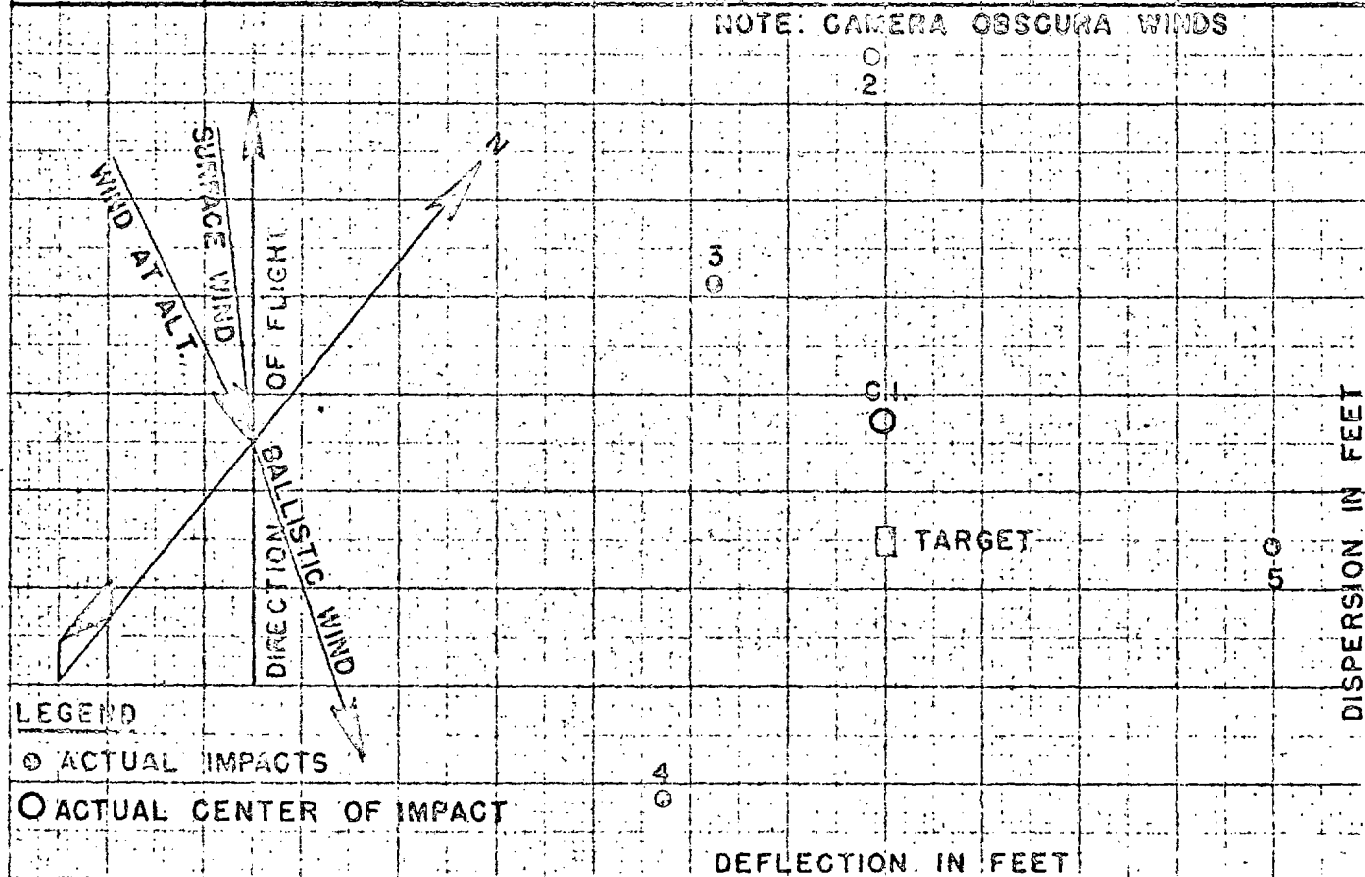PILOT : LT. C.A. PETERSON　　　　　　　　　BOMBARDIER : LIEUT. M.F. SUMMERFELT

SKY :　CLEAR　　　AIR :　　　　TRAIL AND D.S. BASED ON BT-100-B-2

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED				GR'ND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET			
		AIR OBS FT.	GR'ND OBS FT.	CAL IND M/HR	TRUE			GR'ND OBS. M/HR	GR'ND OBS. FT/MIN	FT.	RANGE		DEFLECTION	
					AIR OBS. M/HR	GR'ND OBS. M/HR					OVER FT.	SHORT FT.	RIGHT FT.	LEFT FT.
1	LOST	25430		163										
2	9:46	25430	24853	163	241.3	240.1	158.3	+189.8	7956	498			15
3	9:58	25430	24760	163	241.0	240.4	153.6	-135.3	7757	264			177
4	10:09	25430	24755	164	242.4	241.4	160.8	-157.3	7806		267		228
5	10:30	25430	24777	165	244.0	243.0	162.7	+114.6	7889		6	399	
6														
CENTER OF IMPACT											122			5
MEAN DEVIATION											259		202	

		R.O.S.	R.O.S.	CAMERA
TIME		9:25		10:40
WIND VELOCITY M.P.H.	SURFACE			8.0
	AT ALTITUDE			86.8
	BALLISTIC RANGE WIND			-59.4
	BALLISTIC CROSS WIND			20.2
DENSITY	AT SURFACE			0.998
	BALLISTIC (SURFACE)			1.010
	BALLISTIC (AIR OBS.)	1.003		

NOTE: CAMERA OBSCURA WINDS

LEGEND

⊙ ACTUAL IMPACTS

◯ ACTUAL CENTER OF IMPACT

DEFLECTION IN FEET

DISPERSION IN FEET

200 LT　　O　　RT　200　　　400

37

Appendix C

Individual Standard Elements and Ballistic Coefficients
from Reduction of Field Data

Appendix C

Program, Group, Serial Number	Date of Release, Run No.	Y Standard Altitude ft.	U Standard True Air Speed mi./hr.	X Standard Range ft.	T Standard Time of Flight sec.	λ Standard Trail ft.	C_X	C_T	C_λ
KS-138L-8	3/9/38-1	9000	160	5284			1.81		
9	2			5277			1.76		
12	3			5302			1.94		
10	4			5197	25.19	714	1.36	1.00	1.18
11	5			5214	25.07	669	1.43	1.09	1.26
7	6			5287	25.03	587	1.83	1.12	1.45
KS-138-13	3/21/38-1			5256	24.71	543	1.64	1.48	1.57
18	2			5243	24.74	563	1.57	1.45	1.51
14	3			5293			1.87		
17	4			5251	24.80	569	1.61	1.37	1.50
16	6			5214	24.59	556	1.43	1.69	1.53
19	4/25/38-1	12000		5925			1.28		
20	2			5956			1.37		
22	4			5977			1.44		
23	5			5971			1.42		
24	4/28/38-1	6000		4374	20.06	335	2.07	1.29	1.65
26	3			4363	20.10	352	1.94	1.24	1.56
31	4			4331	20.01	365	1.62	1.39	1.51
27	5			4305	19.96	380	1.43	1.50	1.46
32	6			4365	20.10	352	1.96	1.23	1.57
28	5/2/38-1	15000	160	6651	32.52	980	1.47	1.42	1.45
36	2			6637	32.62	1017	1.43	1.35	1.39
33	3			6582	32.80	1114	1.29	1.24	1.26
37	4			6530	33.01	1217	1.18	1.13	1.16
34	5			6637	32.78	1055	1.43	1.25	1.34

Appendix C (Cont'd)

Program, Group, Serial Number	Date of Release, Run No.	Y Standard Altitude ft.	U Standard True Air Speed mi./hr.	X Standard Range ft.	T Standard Time of Flight sec.	λ Standard Trail ft.	C_X	C_T	C_λ
KS-138-38	5/3/38--1	15000	160	6637	32.87	1077	1.43	1.20	1.31
39	2			6758	32.62	896	1.87	1.35	1.59
40	3			6541	32.49	1084	1.20	1.44	1.30
41	4			6677	32.82	1024	1.55	1.23	1.38
42	5			6550	32.59	1097	1.22	1.37	1.28
43	6			6651	32.71	1026	1.47	1.29	1.38
35	5/6/38--1	12000		5959	29.11	873	1.38	1.20	1.29
48	2			6014	29.03	798	1.58	1.26	1.42
44	3			6055	28.99	747	1.77	1.29	1.52
49	4			5974	29.04	841	1.43	1.25	1.34
46	5			5986	29.13	850	1.47	1.19	1.33
53	5/25/38-1	6000		4297	19.89	371	1.38	1.68	1.49
54	2			4372	20.27	384	2.05	1.01	1.44
55	3			4346	19.98	344	1.75	1.45	1.60
52	4			4379	20.06	330	2.14	1.29	1.68
51	5			4336	20.00	357	1.66	1.42	1.55
RX-138-107	10/31/38-1	7000	180	5239	21.69	487	1.69	1.46	1.58
112	-2			5223	21.57	471	1.59	1.71	1.64
109	3			5260	21.68	464	1.84	1.48	1.66
110	4			5241	21.60	461	1.70	1.63	1.67
111	5			5245	21.61	460	1.73	1.61	1.68
102	1		90	2664	21.31	149	1.87	2.28	2.05
103	2			2681	21.34	136	2.32	2.15	2.25
104	3			2682	21.64	174	2.35	1.35	1.76
105	4			2727	21.77	147	6.19	1.16	2.08

Appendix C (Cont'd)

Program, Group, Serial Number	Date of Release, Run No,	Y Standard Altitude ft.	U Standard True Air Speed mi./hr.	X Standard Range ft.	T Standard Time of Flight sec.	λ Standard Trail ft.	c_X	c_T	c_λ
RX-138-106	10/31/38-5	7000	90	2671	21.47	163	2.04	1.71	1.88
108	11/10/38-1		180	5269	21.60	433	1.91	1.63	1.78
113	2			5242	21.66	476	1.71	1.52	1.62
114	3			5265	21.50	411	1.88	1.88	1.88
115	4			5228	21.63	482	1.62	1.58	1.60
116	5			5244	21.48	427	1.72	1.98	1.82
117	1		90	2668	21.57	179	1.98	1.48	1.71
118	2			2637	21.51	202	1.44	1.61	1.52
119	3			2655	21.52	186	1.69	1.58	1.60
120	4			2653	21.50	185	1.67	1.63	1.65
121	5			2662	21.55	183	1.84	1.52	1.67
KS-138---1	5/3/39--1	2000	160	2578	11.31	77	2.79	1.72	2.28
2	2			2550	11.40	126	1.63	1.09	1.44
3	3			2588	11.36	79	3.73	1.30	2.22
4	4			2568	11.42	111	2.24	1.04	1.68
7	5			2580			2.99		
6	6			2571	11.28	76	2.38	2.20	2.31
9	7			2581	11.33	78	3.02	1.56	2.25
8	8			2578	11.31	77	2.78	1.72	2.25
10	9			2586	11.42	93	3.53	1.04	2.03
5	10			2583			3.20		
11	5/4/39--1			2576	11.30	76	2.68	1.82	2.28
12	2			2577	11.35	87	2.74	1.38	2.09
13	3			2594	11.35	70	4.69	1.39	2.43
14	4			2589	11.31	65	3.92	1.73	2.53

-42-

Program, Group, Serial Number	Date of Release, Run No.	Y Standard Altitude ft.	U Standard True Air Speed mi./hr.	X Standard Range ft.	T Standard Time of Flight sec.	λ Standard Trail ft.	c_X	c_T	c_λ
KS-138-15	5/4/39--5	2000	160	2580	11.26	62	3.00	2.61	3.00
16	6			2584			3.33		
17	7			2589			3.91		
18	8			2579	11.32	76	2.87	1.69	2.28
19	9			2583	11.36	84	3.21	1.30	2.12
20	10			2579			2.91		
1	7/11/39-1	20000		7622	38.43	1396	1.47	1.25	1.35
2	2			7622	38.69	1457	1.47	1.15	1.29
3	3			7643	38.07	1291	1.52	1.42	1.47
4	4			7690	38.19	1271	1.65	1.36	1.50
5	5			7622	38.50	1413	1.47	1.22	1.33
6	6			7694	38.58	1360	1.66	1.19	1.39
7	7			7587	38.32	1405	1.39	1.30	1.34
8	8			7694	38.38	1313	1.66	1.27	1.45
9	11/17/39-1			7666	38.23	1305	1.58	1.34	1.45
10	2			7600	38.55	1447	1.42	1.20	1.30
1	6/21/40-1	25000	200	10519			1.46		
2	2			10462			1.38		
4	4			10378			1.28		
5	5			10664	44.65	2433	1.72	1.01	1.27
7	7/5/40--2			10715			1.83		
8	3			10656	43.65	2149	1.70	1.28	1.46
9	4			10589	43.63	2210	1.58	1.29	1.41
10	5			10546	43.75	2288	1.51	1.25	1.37

Appendix D

Mean Standard Elements of Altitude Groups and Relations
between the Ballistic Coefficients and the Altitude of Release

Appendix D
Table 1
Range

Y	U	V	N	P	X	r_X	c_X	r_{c_X}	c_{X_y}	$X-X_f$
Standard Altitude	Standard True Air Speed	Calibrated Indicated Air Speed Corresponding to Standard True Air Speed	Number of Bombs	Weight of Groups	Mean Standard Range	Probable Error of Mean Standard Range	Ballistic Coefficient Corresponding to Mean Standard Range	Probable Error of Ballistic Coefficient Corresponding to Mean Standard Range	Value of Ballistic Coefficient From C:Y Relation	Mean Standard Range Minus Range Corresponding to c_{X_y}
ft.	mi./hr.	mi./hr.			ft.	ft.				ft.
35000									1.41	
30000									1.43	
25000	200	134.8	8	0.56	10566	26.9	1.54	0.1045	1.46	53
20000	160	116.7	10	0.88	7644	8.5	1.52	0.021	1.49	14
15000	160	126.3	11	0.77	6623	13.7	1.39	0.037	1.54	-51
12000	160	132.4	9	0.63	5980	8.4	1.45	0.029	1.59	-37
10000									1.64	
9000	160	138.8	11	0.77	5256	7.3	1.64	0.042	1.67	-6
7000	180	161.2	10	1.75	5246	3.2	1.73	0.022	1.75	13
7000	90	80.6	10		2670	5.1	2.03	0.128		11
6000	160	145.5	10	0.88	4347	6.2	1.76	0.661	1.82	27
5000									1.90	
2000	160	155.0	20	1.76	2580	1.4	2.93	0.110	2.82	2

Appendix D
Table 2
Time of Flight

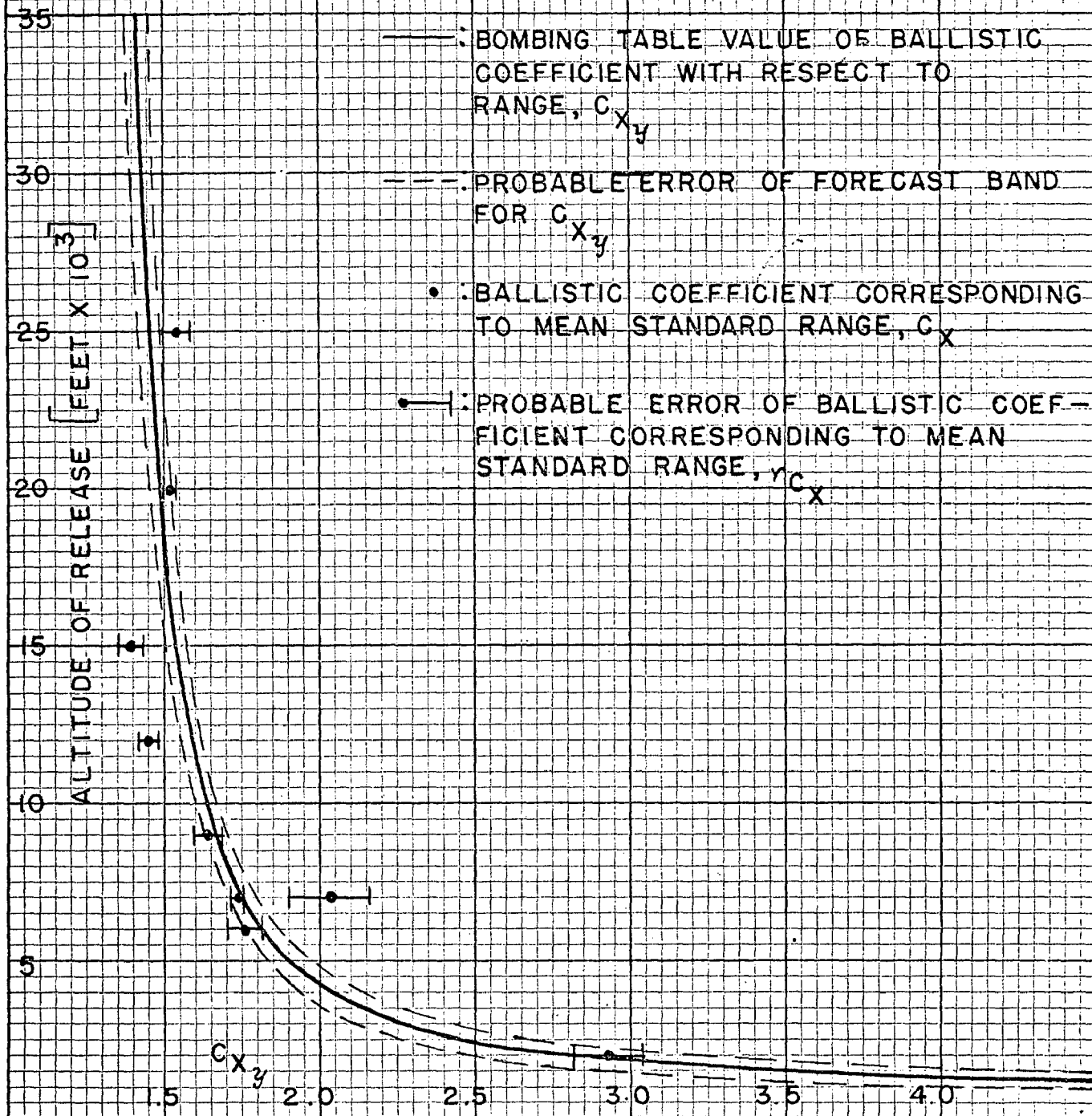| Y	U	V	N	P	T	r_T	C_T	r_{C_T}	C_{T_y}	$T-T_f$
Standard Altitude	Standard True Air Speed	Calibrated Indicated Air Speed Corresponding to Standard True Air Speed	Number of Bombs	Weight of Groups	Mean Standard Time of Flight	Probable Error of Mean Standard Time of Flight	Ballistic Coefficient Corresponding to Mean Standard Time of Flight	Probable Error of Ballistic Coefficient Corresponding to Mean Standard Time of Flight	Value of Ballistic Coefficient From C:Y Relation	Mean Standard Time of Flight Minus Time of Flight Corresponding to C_{T_y}
ft.	mi./hr.	mi./hr.			sec.	sec.				sec.
35000									1.29	
30000									1.29	
25000	200	134.8	4	0.56	43.92	0.164	1.19	0.050	1.29	0.30
20000	160	116.7	10	0.88	38.39	0.042	1.26	0,018	1.29	0.06
15000	160	126.3	11	0.77	32.71	0.049	1.29	0.020	1.29	0.00
12000	160	132.4	5	0.63	29.06	0.018	1.24	0.013	1.29	0.07
10000									1.29	
9000	160	138.8	7	0.77	24.88	0.056	1.28	0.060	1.29	0.02
7000	180	161.2	10	1.75	21.60	0.015	1.64	0.034		-0.18
7000	90	80.6	10		21.52	0.029	1.60	0.071	1.29	-0.11
6000	160	145.5	10	0.88	20.04	0.022	1.33	0.040		-0.02
5000									1.29	
2000	160	155.0	15	1.76	11.34	0.008	1.47	0.066	1.29	-0.03

Appendix D
Table 3
TTrail

Y	U	V	N	P	λ	r_λ	C_λ	r_{C_λ}	C_{λ_y}	$\lambda - \lambda_f$
Standard Altitude	Standard True Air Speed	Calibrated Indicated Air Speed Corresponding to Standard True Air Speed	Number of Bombs	Weight of Groups	Mean Standard Trail	Probable Error of Mean Standard Trail	Ballistic Coefficient Corresponding to Mean Standard Trail	Probable Error of Ballistic Coefficient Corresponding to Mean Standard Trail	Value of Ballistic Coefficient From C:Y Relation	Mean Standard Trail Minus Trail Corresponding to C_{λ_y}
ft.	mi./hr.	mi./hr.			ft.	ft.				ft.
35000									1.32	
30000									1.33	
25000	200	134.8	4	0.56	2270	41.4	1.38	0.028	1.35	-42
20000	160	116.7	10	0.88	1366	14.3	1.38	0.015	1.37	-9
15000	160	126.3	11	0.77	1053	16.6	1.34	0.022	1.41	51
12000	160	132.4	5	0.63	822	15.0	1.37	0.026	1.45	41
10000									1.48	
9000	160	138.8	7	0.77	600	16.6	1.42	0.040	1.50	39
7000	180	161.2	10	1.75	457	5.4	1.69	0.028	1.56	-35
7000	90	80.6	10		170	4.5	1.80	0.048		-20
6000	160	145.5	10	0.88	357	3.9	1.55	0.017	1.60	12
5000									1.66	
2000	160	155.0	15	1.76	82	2.9	2.12	0.076	2.20	3

BT-100-B-3
BOMB, PRACTICE, 100-LB., M38A2
PLOT I

Legend:

———— : BOMBING TABLE VALUE OF BALLISTIC COEFFICIENT WITH RESPECT TO RANGE, C_{X_y}

———— : PROBABLE ERROR OF FORECAST BAND FOR C_{X_y}

• : BALLISTIC COEFFICIENT CORRESPONDING TO MEAN STANDARD RANGE, C_X

•—|— : PROBABLE ERROR OF BALLISTIC COEFFICIENT CORRESPONDING TO MEAN STANDARD RANGE, $_rC_X$

Y-axis: ALTITUDE OF RELEASE $[FEET \times 10^3]$

X-axis: C_{X_y} 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

BT-100-B-3

BOMB, PRACTICE, 100-LB., M38A2

PLOT II

BOMBING TABLE VALUE OF BALLISTIC COEFFICIENT WITH RESPECT TO TIME OF FLIGHT, C_{T_y}

PROBABLE ERROR OF FORECAST BAND FOR C_{T_y}

BALLISTIC COEFFICIENT CORRESPONDING TO MEAN STANDARD TIME OF FLIGHT, C_T

PROBABLE ERROR OF BALLISTIC COEFFICIENT CORRESPONDING TO MEAN STANDARD TIME OF FLIGHT, γ_{C_T}

ALTITUDE OF RELEASE $\left[\text{FEET} \times 10^3\right]$

C_{T_y}

BT-100-B-3

BOMB, PRACTICE, 100-LB., M38A2
PLOT III

c_{λ_y}

————: BOMBING TABLE VALUE OF BALLISTIC COEFFICIENT WITH RESPECT TO TRAIL, c_{λ_y}

— — —: PROBABLE ERROR OF FORECAST BAND FOR c_{λ_y}

• : BALLISTIC COEFFICIENT CORRESPONDING TO MEAN STANDARD TRAIL, c_{λ}

•——| PROBABLE ERROR OF BALLISTIC COEFFICIENT CORRESPONDING TO MEAN STANDARD TRAIL, $r_{c_{\lambda}}$

ALTITUDE OF RELEASE [FEET $\times 10^3$]

35

30

25

20

15

10

5

c_{λ_y}

1.0   1.5   2.0   2.5   3.0   3.5
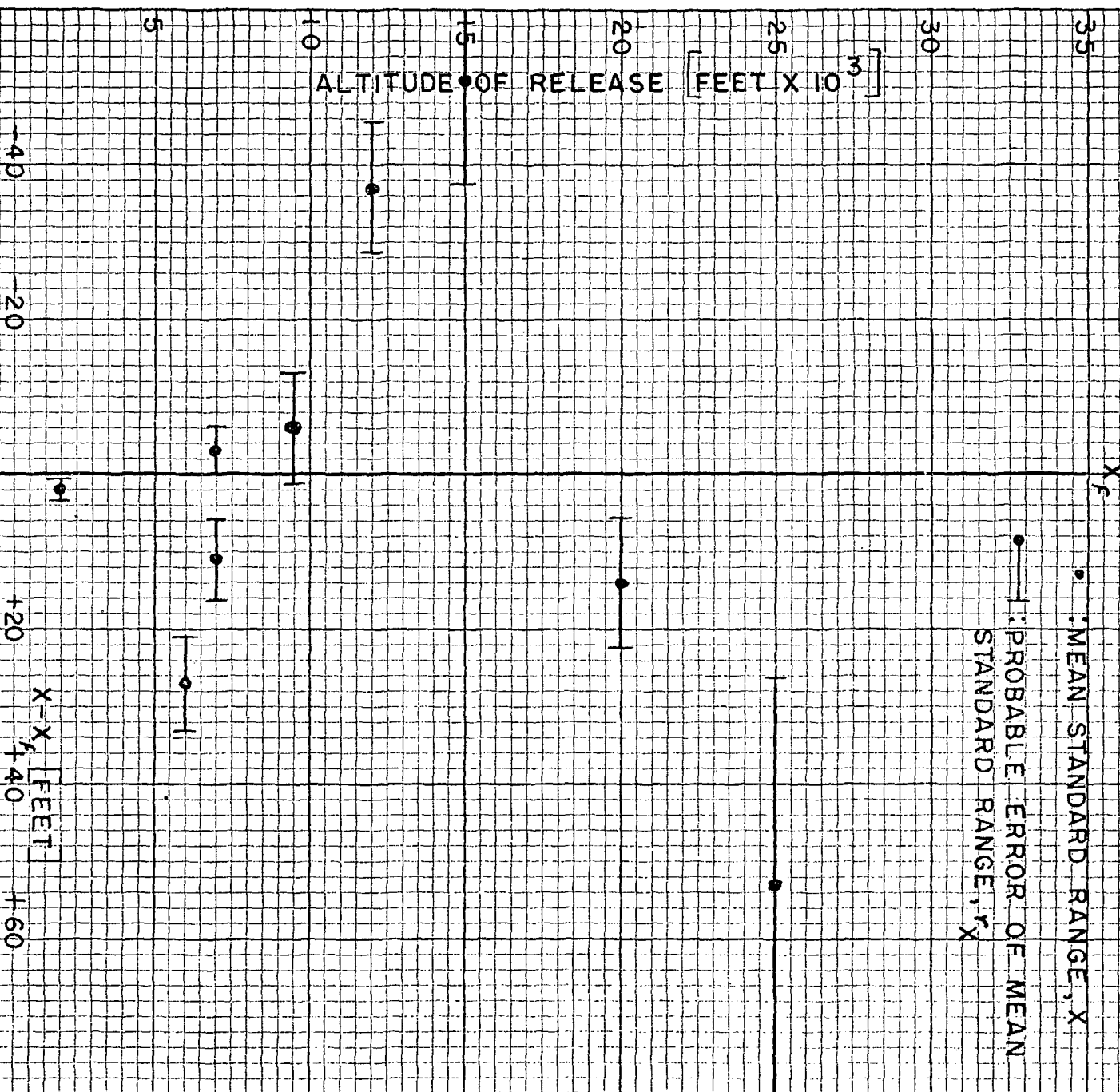
BT-100-B-3

BOMB, PRACTICE, 100-LB., M38A2

PLOT IV

BOMBING TABLE
RANGE

X_f

• :MEAN STANDARD RANGE, X

⊢• :PROBABLE ERROR OF MEAN
     STANDARD RANGE, r_X

ALTITUDE OF RELEASE [FEET X 10³]

X−Xf [FEET]

BT-100-B-3

BOMB, PRACTICE, 100-LB., M38A2

PLOT V

BOMBING TABLE
TIME OF FLIGHT T_f

$\bullet$: MEAN STANDARD TIME OF FLIGHT, T

$\bullet$———|: PROBABLE ERROR OF MEAN STANDARD TIME OF FLIGHT, γ_T

ALTITUDE OF RELEASE $\left[\text{FEET} \times 10^3\right]$

$T - T_f$ [SEC.]

BT-100-B-3

BOMB, PRACTICE, 100-LB., M38A2

PLOT VI