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TM
1941

TM 4-240

WAR DEPARTMENT

U.S. Dept. of Army

TECHNICAL MANUAL

METEOROLOGY FOR COAST ARTILLERY

December 20, 1941

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TECHNICAL MANUAL

METEOROLOGY FOR COAST ARTILLERY

CHANGES No. 1

WAR DEPARTMENT,
WASHINGTON, September 7, 1942.

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TM 4-240, December 20, 1941, is changed as follows:

APPENDIX I

METEOROLOGICAL TABLES

* * * * * * * ★ ★

INSTRUCTIONS FOR USING TABLE X (SUPERSEDED)

1. *General.—a.* Revised table X will be used to determine ballistic air densities for use with guns using high-angle fire; the density weighting factors used in computing these tables are those given in table IX. Revised table XII will be used to determine ballistic air densities for use with guns using low-angle fire; the density weighting factors used in computing these tables are those given in table XI.

b. Revised tables X and XII are each divided into six groups, numbered X–1, X–2, etc. The arabic numeral refers to the corresponding region on the attached map in which the table is valid.

c. Each group of tables except X–5 and XII–5 is further divided into two tables indicating the time of day during which the table is valid. Tables X–5 and XII–5 are valid during both day and night in region 5 (Alaska); in this region diurnal variations are so small that they may be disregarded. Thus table XII–1n is valid in region 1 at night; table XII–3a is valid in region 3 during the afternoon. The limits of night and of afternoon are arbitrarily defined as follows:

Night_____From 2 hours after sunset until 2 hours after sunrise.

Afternoon____ From 5 hours after sunrise until 1 hour before sunset.

d. There are two 3-hour intervals which are not included within the arbitrary limits of night and of afternoon, namely from 1 hour before sunset until 2 hours after sunset, and from 2 hours after sunrise until 5 hours after sunrise. These are transition periods between nighttime conditions and afternoon conditions. If it is desired to obtain ballistic densities corresponding to an observation of surface density taken at a time within one of these 3-hour intervals, an average should be taken of the ballistic densities indicated by the nighttime and the afternoon tables.

e. Whenever the sky is completely overcast, best results will be obtained, irrespective of time of day or night, by using an average of

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the ballistic densities indicated by the nighttime and by the afternoon tables. (See also par. 3.)

2. *Method.*—The method of using the revised ballistic density tables is illustrated by the following examples:

Example 1:

Station—Oklahoma City, Okla. (Elevation 1,282 feet.)
Time—July 16, 1939, 2 AM, 90th meridian time.
Surface data—Pressure: 28.59 inches.
Temperature: 82° F.
Relative humidity: 52 percent.
Computations:
Surface density factor: 92.2 (using table VII).
Corrected surface density factor: 92.5 (using table VIII).
Mean surface density factor: 99 (using table in par. 3*b*).
Departure from mean surface density factor: —6.5.

From the attached map it is seen that Oklahoma City is in region 2. Since the time is 2 AM, turn to tables X–2n and XII–2n to get, by interpolation between the —6.0 and —7.0 values of departure from mean surface density factor, the following departures from mean ballistic density. The corresponding ballistic densities are then obtained by adding the mean ballistic density, in this case 99, to the departures.

Maximum ordinate (feet)	Departures from mean ballistic density		Ballistic density	
	For high-angle fire	For low-angle fire	For high-angle fire	For low-angle fire
Surface	—6.5	—6.5	92.5	92.5
600	—6.7	—6.7	92.3	92.3
1,500	—6.8	—6.9	92.2	92.1
3,000	—7.0	—7.0	92.0	92.0
4,500	—7.0	—7.0	92.0	92.0
6,000	—6.9	—6.8	92.1	92.2
9,000	—6.7	—6.5	92.3	92.5
12,000	—6.5	—6.1	92.5	92.9
15,000	—6.3	—5.7	92.7	93.3
18,000	—6.0	—5.3	93.0	93.7
24,000	—5.6	—4.9	93.4	94.1
30,000	—5.2	—4.7	93.8	94.3

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Example 2:

Station—Washington, D. C. (Elevation 82 feet.)
Time—December 16, 1941, 11 AM, 75th meridian time.
Surface data—Pressure: 30.04 inches.
Temperature: 39° F.
Relative humidity: 54 percent.
Computations:
Surface density factor: 106.2 (using table VII).
Corrected surface density factor: 106.3 (using table VIII).
Mean surface density factor: 103 (using table in par. 3*b* below).
Departure from mean surface density factor: +3.3

From the attached map it is seen that Washington, D. C., is in region 1. In the winter at Washington, D. C., sunrise occurs about 7 AM; 11 AM will therefore be in the transition period between night and afternoon conditions. Turning to tables XII–1n and XII–1a we get, by interpolation, the departures from mean ballistic density which are valid at night and during the afternoon, respectively. The average of these departures will be valid at 11 AM. The corresponding ballistic densities are then obtained by adding the mean ballistic density, in this case 103, to the 11 AM departures.

Maximum ordinate (feet)	Departures from mean ballistic density (for low-angle fire)			Ballistic density (for low-angle fire)
	Night	Afternoon	11 AM	11 AM
Surface	+3.3	+3.3	+3.3	106.3
600	+3.1	+3.3	+3.2	106.2
1,500	+2.7	+3.3	+3.0	106.0
3,000	+2.4	+3.3	+2.9	105.9
4,500	+2.1	+3.3	+2.7	105.7
6,000	+1.8	+3.1	+2.5	105.5
9,000	+1.3	+2.6	+2.0	105.0
12,000	+0.9	+2.2	+1.6	104.6
15,000	+0.6	+1.7	+1.2	104.2
18,000	+0.3	+1.3	+0.8	103.8
24,000	−0.2	+0.6	+0.2	103.2
30,000	−0.8	−0.2	−0.5	102.5

Ballistic densities for high-angle fire could be obtained in a similar way by using tables X–1n and X–1a.

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3. *Effect of cloud and rain.—a.* The following is quoted from Notes on Meteorological Corrections for the Use of Gunners, by D. Brunt and J. Durward (M. O. 241, published by His Majesty's Stationery Office 1921):

"It must be noted that if water particles are present in the atmosphere they will not behave simply like a gas. On encountering the cap of compressed air which immediately precedes a shell, the water drops will acquire some of its velocity, and to this extent they act merely in the sense of increasing the effective density of the air. But in addition to this, a certain fraction of the water drops will be actually picked up by the shell, and by their impact will retard its motion. The "density effect" may be regarded as the minimum and the "impact effect" as the maximum which can be produced. To what extent the "impact effect" actually occurs there is at present no means of knowing exactly, and we are therefore compelled to adopt what seems a reasonable figure. Numerical calculation shows that at ground level the "density effect" of cloud or mist is equivalent to an increase of 0.4 percent in the density of the air, while the maximum "impact effect" of the same is about 10 times as large, or 4 percent. The effects of even very heavy rain are only about one-fifth of these. The practice adopted at Shoeburyness in connection with artillery experiments is to increase the tenuity factor by 2 percent if the trajectory lies wholly in cloud, and proportionally if it is only partly in cloud. The effect of rain is ordinarily so small that it is neglected."

b. Following British practice, it is recommended that the ballistic density be increased by 2 percent if the trajectory lies entirely in fog or cloud, and proportionally if it is only partly in cloud. (See also par. 1*e* above.)

Elevation, in feet, of meteorological datum plane above mean sea level	Mean surface density factor or mean ballistic density	Elevation, in feet, of meteorological datum plane above mean sea level	Mean surface density factor or mean ballistic density
0–300	103	3,300–3,625	92
300–600	102	3,625–3,950	91
600–900	101	3,950–4,275	90
900–1,200	100	4,275–4,600	89
1,200–1,500	99	4,600–4,925	88
1,500–1,800	98	4,925–5,250	87
1,800–2,100	97	5,250–5,575	86
2,100–2,400	96	5,575–5,900	85
2,400–2,700	95	5,900–6,225	84
2,700–3,000	94	6,225–6,550	83
3,000–3,300	93		

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TABLE X-2a.—*Departures from*

FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE
WESTERN

Maximum ordinate (feet)	Departures from mean density factor surface														
	−11.0	−10.0	−9.0	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0	+3.0
600	−10.8	−9.8	−8.8	−7.8	−6.8	−5.8	−4.9	−3.9	−2.9	−1.9	−0.9	+0.1	+1.0	+2.0	+3.0
1,500	−10.6	−9.6	−8.6	−7.6	−6.7	−5.7	−4.8	−3.8	−2.8	−1.8	−0.8	+0.1	+1.0	+2.0	+3.0
3,000	−10.2	−9.2	−8.3	−7.3	−6.4	−5.4	−4.5	−3.5	−2.6	−1.6	−0.7	+0.2	+1.1	+2.0	+2.9
4,500	−9.8	−8.9	−8.0	−7.0	−6.1	−5.1	−4.3	−3.3	−2.4	−1.5	−0.6	+0.3	+1.2	+2.0	+2.9
6,000	−9.5	−8.6	−7.7	−6.7	−5.8	−4.9	−4.0	−3.1	−2.2	−1.4	−0.5	+0.3	+1.2	+2.0	+2.8
9,000	−9.0	−8.1	−7.2	−6.3	−5.4	−4.5	−3.7	−2.9	−2.0	−1.2	−0.4	+0.3	+1.1	+1.8	+2.5
12,000	−8.5	−7.6	−6.8	−5.9	−5.0	−4.2	−3.5	−2.7	−1.9	−1.1	−0.4	+0.3	+0.9	+1.6	+2.2
15,000	−8.1	−7.3	−6.4	−5.6	−4.8	−4.0	−3.3	−2.5	−1.8	−1.1	−0.4	+0.2	+0.8	+1.4	+2.0
18,000	−7.7	−6.9	−6.1	−5.3	−4.5	−3.8	−3.1	−2.4	−1.7	−1.1	−0.5	+0.1	+0.7	+1.2	+1.7
24,000	−7.1	−6.4	−5.6	−4.9	−4.2	−3.5	−2.9	−2.3	−1.7	−1.1	−0.6	−0.1	+0.4	+0.9	+1.4
30,000	−6.6	−5.9	−5.2	−4.6	−3.9	−3.3	−2.8	−2.2	−1.7	−1.2	−0.8	−0.3	+0.1	+0.5	+0.9

TABLE X-3n.—*Departures*

FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRE;

Maximum ordinate (feet)	Departures from mean density factor surface										
	−9.0	−8 0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0
600	−9.3	−8.3	−7.3	−6.3	−5.3	−4.3	−3.3	−2.3	−1.3	−0.3	+0.7	+1.7
1,500	−9.4	−8.4	−7.4	−6.4	−5.4	−4.4	−3.4	−2.4	−1.5	−0.5	+0.5	+1.4
3,000	−9.5	−8.5	−7.5	−6.5	−5.5	−4.5	−3.5	−2.6	−1.6	−0.7	+0.2	+1.2
4,500	−9.5	−8.5	−7.5	−6.5	−5.5	−4.5	−3.5	−2.6	−1.7	−0.8	+0.1	+1.0
6,000	−9.3	−8.3	−7.3	−6.3	−5.4	−4.4	−3.5	−2.5	−1.6	−0.8	+0.1	+0.9
9,000	−8.9	−8.0	−7.0	−6.1	−5.1	−4.2	−3.3	−2.4	−1.5	−0.7	+0.1	+0.8
12,000	−8.5	−7.5	−6.6	−5.7	−4.8	−3.9	−3.1	−2.3	−1.4	−0.7	+0.1	+0.7
15,000	−8.1	−7.2	−6.3	−5.4	−4.6	−3.7	−2.9	−2.1	−1.4	−0.6	0.0	+0.7
18,000	−7.6	−6.8	−5.9	−5.1	−4.3	−3.5	−2.8	−2.0	−1.3	−0.6	0.0	+0.6
24,000	−7.1	−6.3	−5.5	−4.7	−4.0	−3.3	−2.6	−1.9	−1.3	−0.7	−0.1	+0.4
30,000	−6.5	−5.8	−5.1	−4.4	−3.7	−3.1	−2.5	−1.9	−1.3	−0.8	−0.3	+0.2

TABLE X-3a.—*Departures*

FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRE;

Maximum ordinate (feet)	Departures from mean density factor surface										
	−12.0	−11.0	−10.0	−9.0	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0
600	−11.8	−10.8	−9.8	−8.8	−7.8	−6.8	−5.8	−4.8	−3.8	−2.8	−1.9	−0.9
1,500	−11.6	−10.6	−9.6	−8.6	−7.6	−6.6	−5.6	−4.7	−3.7	−2.7	−1.8	−0.8
3,000	−11.3	−10.3	−9.3	−8.3	−7.3	−6.3	−5.3	−4.4	−3.4	−2.5	−1.5	−0.6
4,500	−10.9	−9.9	−9.0	−8.0	−7.0	−6.0	−5.0	−4.1	−3.2	−2.2	−1.4	−0.5
6,000	−10.6	−9.6	−8.6	−7.6	−6.7	−5.7	−4.8	−3.8	−2.9	−2.0	−1.2	−0.3
9,000	−10.0	−9.0	−8.1	−7.1	−6.2	−5.2	−4.3	−3.4	−2.6	−1.7	−0.9	−0.2
12,000	−9.4	−8.4	−7.5	−6.6	−5.7	−4.8	−4.0	−3.1	−2.3	−1.5	−0.8	−0.1
15,000	−8.9	−8.0	−7.1	−6.2	−5.4	−4.5	−3.7	−2.9	−2.1	−1.4	−0.7	0.0
18,000	−8.3	−7.5	−6.7	−5.8	−5.0	−4.2	−3.4	−2.7	−2.0	−1.3	−0.6	0.0
24,000	−7.7	−6.9	−6.1	−5.4	−4.6	−3.9	−3.2	−2.5	−1.8	−1.2	−0.6	−0.1
30,000	−7.0	−6.3	−5.6	−4.9	−4.2	−3.6	−3.0	−2.4	−1.8	−1.2	−0.7	−0.3

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mean ballistic density

FIRE; VALID DURING THE AFTERNOON IN REGION 2 (MID-U. S. A.)

Departures from mean density factor surface—Continued														Maximum ordinate (feet)
+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	+11.0	+12.0	+13.0	+14.0	+15.0	+16.0	+17.0	+18.0	
+3.9	+4.9	+5.9	+6.8	+7.8	+8.7	+9.7	+10.7	+11.6	+12.6	+13.6	+14.6	+15.6	+16.5	+17.5	600.
+3.9	+4.8	+5.8	+6.6	+7.6	+8.5	+9.4	+10.3	+11.2	+12.2	+13.2	+14.2	+15.1	+16.1	+17.0	1,500.
+3.8	+4.6	+5.5	+6.3	+7.2	+8.0	+8.8	+9.7	+10.6	+11.5	+12.4	+13.4	+14.4	+15.2	+16.1	3,000.
+3.7	+4.5	+5.3	+6.0	+6.8	+7.6	+8.3	+9.1	+9.9	+10.8	+11.7	+12.6	+13.7	+14.4	+15.3	4,500
+3.5	+4.2	+5.0	+5.7	+6.4	+7.1	+7.8	+8.5	+9.3	+10.1	+11.0	+11.9	+12.9	+13.6	+14.5	6,000.
+3.2	+3.8	+4.5	+5.1	+5.7	+6.3	+6.9	+7.6	+8.3	+9.0	+9.8	+10.6	+11.6	+12.3	+13.1	9,000.
+2.8	+3.4	+4.0	+4.5	+5.1	+5.6	+6.2	+6.8	+7.4	+8.1	+8.9	+9.6	+10.4	+11.1	+11.9	12,000.
+2.5	+3.1	+3.6	+4.1	+4.6	+5.1	+5.6	+6.2	+6.8	+7.4	+8.1	+8.8	+9.6	+10.2	+10.9	15,000.
+2.2	+2.7	+3.2	+3.7	+4.1	+4.6	+5.1	+5.6	+6.1	+6.7	+7.4	+8.0	+8.7	+9.3	+10.0	18,000.
+1.8	+2.2	+2.6	+3.0	+3.4	+3.9	+4.3	+4.7	+5.2	+5.7	+6.3	+6.9	+7.5	+8.1	+8.7	24,000.
+1.2	+1.6	+2.0	+2.3	+2.6	+3.0	+3.3	+3.7	+4.1	+4.5	+5.0	+5.5	+6.1	+6.6	+7.2	30,000

from mean ballistic density

VALID DURING THE NIGHT IN REGION 3 (WESTERN U. S. A.)

Departures from mean density factor surface—Continued											Maximum ordinate (feet)
+3.0	+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	+11.0	+12.0	+13.0	+14.0	
+2.6	+3.6	+4.6	+5.6	+6.5	+7.5	+8.5	+9.4	+10.4	+11.4	+12.3	+13.3	600.
+2.3	+3.3	+4.2	+5.2	+6.1	+7.0	+8.0	+8.8	+9.8	+10.7	+11.6	+12.6	1,500.
+2.0	+2.9	+3.8	+4.7	+5.5	+6.4	+7.3	+8.1	+9.0	+9.8	+10.7	+11.5	3,000.
+1.8	+2.7	+3.5	+4.3	+5.1	+5.9	+6.7	+7.5	+8.3	+9.1	+9.9	+10.7	4,500.
+1.7	+2.5	+3.3	+4.0	+4.7	+5.5	+6.2	+6.9	+7.7	+8.4	+9.2	+10.0	6,000.
+1.5	+2.2	+2.9	+3.6	+4.2	+4.8	+5.5	+6.1	+6.8	+7.5	+8.1	+8.9	9,000.
+1.4	+2.0	+2.6	+3.2	+3.8	+4.3	+4.9	+5.5	+6.1	+6.7	+7.3	+8.0	12,000.
+1.3	+1.8	+2.4	+2.9	+3.4	+3.9	+4.5	+5.0	+5.5	+6.1	+6.7	+7.3	15,000.
+1.1	+1.7	+2.2	+2.6	+3.1	+3.6	+4.1	+4.5	+5.0	+5.5	+6.0	+6.6	18,000
+0.9	+1.4	+1.8	+2.2	+2.6	+3.0	+3.4	+3.8	+4.2	+4.6	+5.1	+5.5	24,000.
+0.6	+1.0	+1.4	+1.7	+2.1	+2.4	+2.7	+3.0	+3.3	+3.6	+3.9	+4.2	30,000.

from mean ballistic density

VALID DURING THE AFTERNOON IN REGION 3 (WESTERN U. S. A.)

Departures from mean density factor surface—Continued												Maximum ordinate (feet)
0.0	+1.0	+2.0	+3.0	+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	+11.0	+12.0	
+0.1	+1.1	+2.0	+3.0	+4.0	+4.9	+5.9	+6.8	+7.8	+8.8	+9.7	+10.7	+11.7	600.
+0.2	+1.1	+2.0	+3.0	+3.9	+4.8	+5.8	+6.7	+7.6	+8.6	+9.4	+10.4	+11.3	1,500.
+0.3	+1.2	+2.0	+2.9	+3.8	+4.6	+5.5	+6.4	+7.2	+8.1	+9.0	+9.8	+10.7	3,000.
+0.4	+1.2	+2.0	+2.9	+3.7	+4.5	+5.3	+6.1	+6.9	+7.7	+8.5	+9.3	+10.1	4,500.
+0.5	+1.3	+2.0	+2.8	+3.5	+4.3	+5.0	+5.7	+6.5	+7.3	+8.0	+8.8	+9.6	6,000.
+0.6	+1.3	+2.0	+2.6	+3.3	+3.9	+4.6	+5.2	+5.9	+6.5	+7.2	+8.0	+8.7	9,000.
+0.6	+1.2	+1.8	+2.4	+3.0	+3.6	+4.2	+4.7	+5.3	+5.9	+6.6	+7.2	+7.9	12,000.
+0.6	+1.2	+1.7	+2.3	+2.8	+3.3	+3.8	+4.4	+4.9	+5.5	+6.0	+6.6	+7.2	15,000.
+0.6	+1.1	+1.6	+2.1	+2.6	+3.0	+3.5	+4.0	+4.5	+5.0	+5.5	+6.0	+6.6	18,000.
+0.4	+0.9	+1.4	+1.8	+2.2	+2.6	+3.0	+3.4	+3.8	+4.2	+4.6	+5.1	+5.5	24,000.
+0.2	+0.6	+1.0	+1.4	+1.7	+2.0	+2.4	+2.6	+2.9	+3.2	+3.5	+3.9	+4.2	30,000.

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TABLE X–4n.—*Departures from mean ballistic density*

FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRE; VALID DURING THE NIGHT IN REGION 4 (CALIFORNIA COAST)

Maximum ordinate (feet)	Departures from mean density factor surface												Maximum ordinate (feet)
	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0	+3.0	+4.0	+5.0	
600	−6.1	−5.1	−4.1	−3.1	−2.1	−1.1	−0.2	+0.7	+1.7	+2.6	+3.5	+4.4	600.
1,500	−6.1	−5.1	−4.1	−3.1	−2.2	−1.2	−0.4	+0.5	+1.4	+2.2	+3.0	+3.7	1,500.
3,000	−6.2	−5.2	−4.2	−3.3	−2.3	−1.5	−0.6	+0.2	+0.9	+1.6	+2.3	+3.0	3,000.
4,500	−6.4	−5.4	−4.4	−3.4	−2.5	−1.6	−0.8	−0.1	+0.7	+1.3	+1.9	+2.5	4,500.
6,000	−6.5	−5.5	−4.5	−3.5	−2.6	−1.7	−0.9	−0.2	+0.5	+1.1	+1.6	+2.2	6,000.
9,000	−6.5	−5.5	−4.5	−3.6	−2.7	−1.8	−1.1	−0.4	+0.2	+0.8	+1.3	+1.8	9,000.
12,000	−6.4	−5.4	−4.5	−3.6	−2.7	−1.9	−1.2	−0.5	+0.1	+0.5	+1.0	+1.5	12,000.
15,000	−6.2	−5.3	−4.4	−3.5	−2.7	−1.9	−1.2	−0.6	−0.1	+0.4	+0.8	+1.3	15,000.
18,000	−5.9	−5.1	−4.3	−3.5	−2.7	−1.9	−1.3	−0.7	−0.2	+0.2	+0.6	+1.0	18,000.
24,000	−5.5	−4.8	−4.0	−3.3	−2.6	−1.9	−1.3	−0.8	−0.3	0.0	+0.3	+0.7	24,000.
30,000	−5.2	−4.5	−3.8	−3.2	−2.5	−1.9	−1.4	−0.9	−0.5	−0.2	0.0	+0.3	30,000.

TABLE X–4a.—*Departures from mean ballistic density*

FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRE; VALID DURING THE AFTERNOON IN REGION 4 (CALIFORNIA COAST)

Maximum ordinate (feet)	Departures from mean density factor surface											Maximum ordinate (feet)
	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0	+3.0	
600	−7.9	−6.9	−5.9	−4.9	−3.9	−2.9	−2.0	−1.0	0.0	+0.9	+1.9	+2.8	600.
1,500	−7.8	−6.8	−5.8	−4.8	−3.8	−2.8	−1.9	−1.0	0.0	+0.8	+1.8	+2.6	1,500.
3,000	−7.7	−6.7	−5.7	−4.7	−3.7	−2.7	−1.9	−1.0	0.0	+0.7	+1.5	+2.2	3,000.
4,500	−7.6	−6.6	−5.6	−4.6	−3.6	−2.6	−1.8	−0.9	−0.1	+0.7	+1.3	+2.0	4,500.
6,000	−7.4	−6.4	−5.4	−4.4	−3.5	−2.6	−1.7	−0.9	−0.1	+0.6	+1.2	+1.8	6,000.
9,000	−7.2	−6.3	−5.3	−4.3	−3.4	−2.5	−1.7	−0.9	−0.2	+0.4	+1.0	+1.5	9,000.
12,000	−6.9	−6.0	−5.1	−4.1	−3.2	−2.4	−1.6	−0.9	−0.3	+0.3	+0.8	+1.3	12,000.
15,000	−6.6	−5.8	−4.9	−4.0	−3.1	−2.3	−1.6	−0.9	−0.3	+0.1	+0.6	+1.1	15,000.
18,000	−6.3	−5.5	−4.6	−3.8	−3.0	−2.3	−1.6	−0.9	−0.4	0.0	+0.4	+0.9	18,000.
24,000	−5.9	−5.1	−4.4	−3.6	−2.9	−2.2	−1.5	−1.0	−0.5	−0.1	+0.2	+0.6	24,000.
30,000	−5.4	−4.8	−4.1	−3.4	−2.8	−2.1	−1.6	−1.0	−0.7	−0.4	−0.1	+0.2	30,000.

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TABLE X-5.—*Departures*

FOR ANTIAIRCRAFT ARTILLERY AND OTHER

Maximum ordinate (feet)	Departures from mean density factor surface													
	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0	+3.0	+4.0	+5.0	+6.0	+7.0
600	−5.8	−4.9	−3.9	−2.9	−2.0	−1.0	0.0	+1.0	+1.9	+2.9	+3.8	+4.8	+5.7	+6.7
1,500	−5.7	−4.8	−3.8	−2.8	−1.9	−1.0	0.0	+0.9	+1.8	+2.8	+3.7	+4.6	+5.4	+6.3
3,000	−5.4	−4.5	−3.6	−2.7	−1.8	−0.9	0.0	+0.9	+1.7	+2.6	+3.4	+4.3	+5.0	+5.8
4,500	−5.2	−4.3	−3.4	−2.5	−1.7	−0.8	0.0	+0.9	+1.7	+2.5	+3.3	+4.1	+4.7	+5.4
6,000	−4.9	−4.1	−3.2	−2.4	−1.6	−0.8	+0.1	+0.9	+1.6	+2.4	+3.1	+3.8	+4.4	+5.0
9,000	−4.5	−3.7	−2.9	−2.1	−1.4	−0.7	+0.1	+0.8	+1.6	+2.3	+2.9	+3.5	+4.0	+4.5
12,000	−4.1	−3.4	−2.7	−2.0	−1.3	−0.6	+0.1	+0.8	+1.5	+2.1	+2.7	+3.2	+3.6	+4.0
15,000	−3.8	−3.2	−2.5	−1.8	−1.2	−0.6	+0.1	+0.7	+1.4	+1.9	+2.5	+3.0	+3.3	+3.7
18,000	−3.6	−3.0	−2.4	−1.8	−1.2	−0.6	+0.1	+0.6	+1.2	+1.8	+2.2	+2.7	+3.1	+3.4
24,000	−3.4	−2.8	−2.3	−1.7	−1.2	−0.6	−0.1	+0.4	+0.9	+1.4	+1.9	+2.3	+2.6	+2.9
30,000	−3.2	−2.8	−2.3	−1.8	−1.3	−0.8	−0.4	+0.1	+0.5	+0.9	+1.3	+1.6	+1.9	+2.2

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from mean ballistic density

HIGH-ANGLE FIRE; VALID IN REGION 5 (ALASKA)

Departures from mean density factor surface—Continued															Maximum ordinate (feet)
+8.0	+9.0	+10.0	+11.0	+12.0	+13.0	+14.0	+15.0	+16.0	+17.0	+18.0	+19.0	+20.0	+21.0	+22.0	
+7.6	+8.5	+9.4	+10.3	+11.2	+12.1	+13.1	+14.0	+15.0	+16.0	+17.0	+18.0	+19.0	+20.0	+21.0	600.
+7.2	+8.0	+8.9	+9.7	+10.6	+11.4	+12.3	+13.2	+14.1	+15.0	+16.0	+17.0	+18.0	+19.0	+20.0	1,500.
+6.5	+7.3	+8.0	+8.7	+9.5	+10.2	+11.0	+11.8	+12.7	+13.6	+14.6	+15.5	+16.5	+17.5	+18.5	3,000.
+6.0	+6.7	+7.3	+7.9	+8.6	+9.2	+9.9	+10.7	+11.6	+12.5	+13.5	+14.4	+15.4	+16.4	+17.4	4,500.
+5.6	+6.2	+6.7	+7.3	+7.9	+8.4	+9.0	+9.8	+10.7	+11.6	+12.5	+13.5	+14.5	+15.4	+16.4	6,000.
+5.0	+5.4	+5.9	+6.4	+6.8	+7.3	+7.8	+8.5	+9.3	+10.2	+11.1	+12.0	+12.9	+13.9	+14.8	9,000.
+4.5	+4.8	+5.2	+5.6	+6.0	+6.5	+6.9	+7.5	+8.3	+9.1	+10.0	+10.8	+11.7	+12.6	+13.5	12,000.
+4.1	+4.4	+4.8	+5.1	+5.5	+5.8	+6.2	+6.8	+7.5	+8.3	+9.1	+10.0	+10.8	+11.7	+12.5	15,000.
+3.7	+4.0	+4.3	+4.6	+4.9	+5.3	+5.6	+6.1	+6.8	+7.6	+8.3	+9.1	+9.9	+10.8	+11.6	18,000.
+3.1	+3.4	+3.7	+3.9	+4.2	+4.5	+4.7	+5.2	+5.8	+6.5	+7.2	+8.0	+8.7	+9.5	+10.3	24,000.
+2.4	+2.6	+2.8	+3.0	+3.2	+3.5	+3.7	+4.1	+4.6	+5.2	+5.9	+6.6	+7.3	+8.0	+8.8	30,000.

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TABLE X-6n.—*Departures from mean ballistic density*

FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRE; VALID DURING THE NIGHT IN REGION 6 (WEST INDIES, CANAL ZONE, AND HAWAII)

Maximum ordinate (feet)	Departures from mean density factor surface							Maximum ordinate (feet)
	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	
600	−6.9	−5.9	−4.9	−3.9	−2.9	−1.9	−0.9	600.
1,500	−6.8	−5.8	−4.8	−3.9	−2.9	−1.9	−0.9	1,500.
3,000	−6.6	−5.7	−4.7	−3.8	−2.8	−1.8	−0.9	3,000.
4,500	−6.4	−5.5	−4.6	−3.6	−2.7	−1.8	−0.8	4,500.
6,000	−6.2	−5.4	−4.4	−3.5	−2.6	−1.6	−0.7	6,000.
9,000	−6.0	−5.2	−4.2	−3.3	−2.4	−1.5	−0.5	9,000.
12,000	−5.7	−5.0	−4.1	−3.2	−2.3	−1.4	−0.5	12,000.
15,000	−5.5	−4.8	−4.0	−3.1	−2.3	−1.4	−0.6	15,000.
18,000	−5.4	−4.7	−3.9	−3.1	−2.3	−1.5	−0.7	18,000.
24,000	−5.1	−4.6	−3.8	−3.1	−2.4	−1.7	−1.0	24,000.
30,000	−5.0	−4.5	−3.8	−3.2	−2.5	−1.9	−1.2	30,000.

TABLE X-6a.—*Departures from mean ballistic density*

FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRE; VALID DURING THE AFTERNOON IN REGION 6 (WEST INDIES, CANAL ZONE, AND HAWAII)

Maximum ordinate (feet)	Departures from mean density factor surface								Maximum ordinate (feet)
	−9.0	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	
600	−8.8	−7.8	−6.8	−5.8	−4.8	−3.8	−2.8	−1.8	600.
1,500	−8.6	−7.6	−6.6	−5.6	−4.6	−3.6	−2.6	−1.6	1,500.
3,000	−8.1	−7.2	−6.3	−5.3	−4.3	−3.3	−2.3	−1.3	3,000.
4,500	−7.8	−6.9	−5.9	−5.0	−4.0	−3.0	−2.0	−1.0	4,500.
6,000	−7.4	−6.5	−5.6	−4.7	−3.7	−2.7	−1.7	−0.8	6,000.
9,000	−6.9	−6.1	−5.2	−4.3	−3.3	−2.4	−1.4	−0.5	9,000.
12,000	−6.5	−5.8	−4.9	−4.0	−3.1	−2.2	−1.3	−0.4	12,000.
15,000	−6.2	−5.5	−4.7	−3.9	−3.0	−2.1	−1.3	−0.4	15,000.
18,000	−6.0	−5.3	−4.5	−3.8	−3.0	−2.1	−1.3	−0.5	18,000.
24,000	−5.7	−5.1	−4.4	−3.7	−3.0	−2.2	−1.5	−0.8	24,000.
30,000	−5.4	−4.9	−4.3	−3.6	−3.0	−2.3	−1.7	−1.0	30,000.

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INSTRUCTIONS FOR USING TABLE XII (SUPERSEDED)

Table XII is used to determine ballistic densities for "message 3." The weighting factors in table XI were used in computing table XII.

The instructions for use of table XII are the same as the instructions for the use of table X.

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TABLE XII

TABLE XII-1n.—*Departures*

FOR TERRESTRIAL ARTILLERY EXCEPTING HIGH-ANGLE FIRE;

Maximum ordinate (feet)	Departures from mean density factor at surface											
	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0	+3.0
600	−8.0	−7.0	−6.0	−5.1	−4.1	−3.2	−2.2	−1.2	−0.2	+0.7	+1.7	+2.8
1,500	−8.0	−6.9	−6.0	−5.2	−4.3	−3.4	−2.5	−1.6	−0.6	+0.4	+1.4	+2.4
3,000	−7.9	−6.7	−6.0	−5.2	−4.4	−3.6	−2.7	−1.8	−0.9	+0.1	+1.0	+2.1
4,500	−7.8	−6.6	−5.9	−5.1	−4.3	−3.5	−2.7	−1.9	−1.0	−0.1	+0.8	+1.8
6,000	−7.6	−6.4	−5.7	−5.0	−4.2	−3.4	−2.6	−1.9	−1.0	−0.2	+0.6	+1.5
9,000	−7.1	−6.0	−5.3	−4.7	−4.0	−3.3	−2.6	−1.8	−1.2	−0.4	+0.4	+1.1
12,000	−6.6	−5.7	−5.0	−4.4	−3.8	−3.2	−2.5	−1.9	−1.3	−0.6	0.0	+0.7
15,000	−6.2	−5.3	−4.8	−4.2	−3.6	−3.1	−2.5	−1.9	−1.4	−0.8	−0.2	+0.4
18,000	−5.8	−5.1	−4.6	−4.1	−3.5	−3.0	−2.5	−1.9	−1.5	−0.9	−0.4	+0.1
24,000	−5.4	−4.9	−4.3	−3.9	−3.4	−3.0	−2.5	−2.1	−1.6	−1.2	−0.8	−0.4
30,000	−5.3	−4.8	−4.3	−3.9	−3.5	−3.1	−2.7	−2.3	−2.0	−1.6	−1.3	−0.9

TABLE XII-1a.—*Departures*

FOR TERRESTRIAL ARTILLERY EXCEPTING HIGH-ANGLE FIRE;

Maximum ordinate (feet)	Departures from mean density factor at surface												
	−11.0	−10.0	−9.0	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0
600	−10.8	−9.7	−8.7	−7.8	−6.8	−5.8	−4.8	−3.9	−2.9	−1.9	−0.9	+0.1	+1.1
1,500	−10.5	−9.4	−8.4	−7.5	−6.5	−5.6	−4.6	−3.7	−2.7	−1.8	−0.8	+0.2	+1.2
3,000	−9.9	−8.8	−7.8	−6.9	−6.0	−5.1	−4.2	−3.4	−2.5	−1.5	−0 6	+0.3	+1.3
4,500	−9.3	−8.2	−7.2	−6.4	−5.6	−4.7	−3.8	−3.0	−2.2	−1.3	−0.4	+0.5	+1.4
6,000	−8.9	−7.8	−6.8	−6.0	−5.2	−4.4	−3.6	−2.8	−2.0	−1.2	−0.4	+0.5	+1.3
9,000	−8.1	−7.1	−6.2	−5.5	−4.8	−4.1	−3.3	−2.6	−1.9	−1.2	−0.4	+0.3	+1.0
12,000	−7.4	−6.5	−5.7	−5.1	−4.4	−3.8	−3.2	−2.5	−1.9	−1.2	−0.6	+0.0	+0.7
15,000	−6.8	−6.0	−5.4	−4.8	−4.2	−3.6	−3.0	−2.5	−1.9	−1.3	−0.7	−0.2	+0.4
18,000	−6.4	−5.7	−5.1	−4.6	−4.0	−3.5	−3.0	−2.4	−1.9	−1.4	−0.9	−0.4	+0.1
24,000	−5.9	−5.3	−4.8	−4.3	−3.8	−3.4	−2.9	−2.5	−2.0	−1.6	−1.2	−0.7	−0.3
30,000	−5.6	−5.2	−4.7	−4.3	−3.8	−3.4	−3.0	−2.7	−2.3	−1.9	−1.6	−1.3	−0.9

TABLE XII-2n.—*Departures*

FOR TERRESTRIAL ARTILLERY EXCEPTING HIGH-ANGLE FIRE;

Maximum ordinate (feet)	Departures from mean density factor at surface													
	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0	+3.0	+4.0	+5.0	+6.0
600	−8.1	−7.2	−6.2	−5.3	−4.3	−3.3	−2.4	−1.4	−0.4	+0.6	+1.6	+2.6	+3.6	+4.6	+5.6
1,500	−8.4	−7.4	−6.5	−5.5	−4.6	−3.6	−2.7	−1.7	−0.7	+0.3	+1.2	+2.2	+3.1	+4.1	+5.1
3,000	−8.4	−7.5	−6.6	−5.7	−4.7	−3.8	−2.9	−2.0	−1.1	−0.1	+0.7	+1.7	+2.6	+3.5	+4.4
4,500	−8.4	−7.5	−6.6	−5.7	−4.8	−3.9	−3.0	−2.1	−1.2	−0.3	+0.5	+1.4	+2.2	+3.0	+3.8
6,000	−8.2	−7.3	−6.4	−5.6	−4.7	−3.8	−3.0	−2.1	−1.3	−0.5	+0.3	+1.1	+1.9	+2.6	+3.4
9,000	−7.9	−7.0	−6.1	−5.3	−4.4	−3.6	−2.8	−2.1	−1.3	−0.6	+0.1	+0.8	+1.4	+2.1	+2.7
12,000	−7.4	−6.5	−5.7	−4.9	−4.1	−3.4	−2.7	−2.0	−1.3	−0.7	−0.1	+0.5	+1.1	+1.7	+2.2
15,000	−6.8	−6.1	−5.3	−4.6	−3.9	−3.2	−2.6	−1.9	−1.3	−0.8	−0.2	+0.3	+0.8	+1.3	+1.8
18,000	−6.4	−5.7	−5.0	−4.3	−3.7	−3.1	−2.5	−1.9	−1.4	−0.8	−0.4	+0.1	+0.6	+1.0	+1.5
24,000	−5.9	−5.2	−4.6	−4.0	−3.4	−2.9	−2.4	−1.9	−1.5	−1.0	−0.6	−0.2	+0.1	+0.5	+0.8
30,000	−5.6	−5.0	−4.4	−3.9	−3.4	−2.9	−2.5	−2.1	−1.8	−1.4	−1.1	−0.8	−0.5	−0.3	0.0

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(SUPERSEDED)

from mean ballistic density

VALID DURING THE NIGHT IN REGION 1 (EASTERN U. S. A.)

Departures from mean density factor at surface—Continued													Maximum ordinate (feet)
+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	+11.0	+12.0	+13.0	+14.0	+15.0	+16.0	
+3.8	+4.8	+5.8	+6.8	+7.8	+8.7	+9.7	+10.7	+11.6	+12.6	+13.5	+14.5	+15.4	600.
+3.5	+4.5	+5.5	+6.4	+7.4	+8.3	+9.3	+10.2	+11.0	+11.9	+12.8	+13.7	+14.6	1,500.
+3.1	+4.0	+4.9	+5.8	+6.7	+7.6	+8.5	+9.3	+10.1	+11.0	+11.8	+12.7	+13.5	3,000.
+2.7	+3.6	+4.5	+5.3	+6.1	+6.9	+7.8	+8.5	+9.2	+10.0	+10.8	+11.7	+12.5	4,500.
+2.4	+3.2	+4.0	+4.8	+5.6	+6.3	+7.1	+7.9	+8.4	+9.2	+9.9	+10.6	+11.4	6,000.
+1.9	+2.6	+3.3	+4.0	+4.6	+5.3	+6.0	+6.6	+7.1	+7.7	+8.4	+9.0	+9.6	9,000.
+1.4	+2.0	+2.6	+3.3	+3.8	+4.4	+5.0	+5.7	+6.1	+6.6	+7.2	+7.7	+8.3	12,000.
+1.0	+1.5	+2.1	+2.6	+3.2	+3.7	+4.3	+4.9	+5.2	+5.7	+6.1	+6.6	+7.1	15,000.
+0.6	+1.1	+1.6	+2.1	+2.6	+3.1	+3.7	+4.2	+4.4	+4.9	+5.3	+5.7	+6.2	18,000.
+0.1	+0.5	+0.9	+1.3	+1.7	+2.1	+2.6	+3.0	+3.1	+3.4	+3.7	+4.1	+4.4	24,000.
−0.7	−0.3	0.0	+0.3	+0.6	+0.9	+1.3	+1.7	+1.6	+1.9	+2.1	+2.4	+2.7	30,000.

from mean ballistic density

VALID DURING THE AFTERNOON IN REGION 1 (EASTERN U. S. A.)

Departures from mean density factor at surface—Continued												Maximum ordinate (feet)
+2.0	+3.0	+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	+11.0	+12.0	+13.0	+14.0	
+2.0	+3.0	+4.0	+5.0	+6.0	+6.9	+7.9	+8.9	+9.8	+10.8	+11.8	+12.8	+13.8	600.
+2.1	+3.0	+4.0	+4.9	+5.9	+6.8	+7.7	+8.7	+9.5	+10.5	+11.5	+12.4	+13.4	1,500.
+2.1	+3.1	+3.9	+4.8	+5.7	+6.5	+7.4	+8.3	+9.1	+10.0	+10.9	+11.8	+12.8	3,000.
+2.2	+3.1	+3.9	+4.7	+5.5	+6.3	+7.1	+7.9	+8.6	+9.5	+10.3	+11.2	+12.2	4,500.
+2.1	+2.9	+3.7	+4.4	+5.2	+5.9	+6.7	+7.4	+8.0	+8.8	+9.6	+10.3	+11.2	6,000.
+1.7	+2.4	+3.1	+3.8	+4.4	+5.1	+5.8	+6.4	+6.9	+7.6	+8.2	+8.9	+9.5	9,000.
+1.3	+2.0	+2.5	+3.2	+3.7	+4.3	+5.0	+5.5	+6.0	+6.5	+7.1	+7.7	+8.3	12,000.
+1.0	+1.5	+2.0	+2.6	+3.1	+3.7	+4.3	+4.7	+5.1	+5.6	+6.1	+6.6	+7.1	15,000.
+0.6	+1.1	+1.6	+2.1	+2.6	+3.1	+3.7	+4.0	+4.4	+4.8	+5.3	+5.7	+6.2	18,000.
+0.1	+0.5	+0.9	+1.3	+1.7	+2.1	+2.6	+2.8	+3.1	+3.4	+3.7	+4.1	+4.4	24,000.
−0.6	−0.3	0.0	+0.3	+0.6	+0.9	+1.3	+1.5	+1.6	+1.9	+2.1	+2.4	+2.7	30,000.

from mean ballistic density

VALID DURING THE NIGHT IN REGION 2 (MIDWESTERN U. S. A)

Departures from mean density factor at surface—Continued														Maximum ordinate (feet)
+7.0	+8.0	+9.0	+10.0	+11.0	+12.0	+13.0	+14.0	+15.0	+16.0	+17.0	+18.0	+19.0	+20.0	+21.0	
+6.6	+7.6	+8.5	+9.5	+10.4	+11.4	+12.3	+13.3	+14.2	+15.1	+16.1	+17.0	+17.9	+18.8	+19.8	600.
+6.0	+7.0	+7.9	+8.8	+9.7	+10.7	+11.5	+12.4	+13.2	+14.1	+14.9	+15.7	+16.5	+17.3	+18.1	1,500.
+5.3	+6.2	+7.0	+7.8	+8.6	+9.4	+10.2	+11.0	+11.7	+12.5	+13.2	+13.9	+14.7	+15.4	+16.1	3,000.
+4.6	+5.4	+6.1	+6.8	+7.5	+8.2	+8.8	+9.5	+10.2	+10.9	+11.7	+12.4	+13.2	+13.9	+14.7	4,500.
+4.1	+4.8	+5.4	+6.0	+6.6	+7.3	+7.9	+8.5	+9.2	+9.9	+10.6	+11.3	+12.1	+12.8	+13.5	6,000.
+3.3	+3.9	+4.4	+4.9	+5.5	+6.0	+6.5	+7.1	+7.7	+8.3	+9.0	+9.6	+10.2	+10.9	+11.6	9,000.
+2.7	+3.2	+3.7	+4.2	+4.7	+5.1	+5.6	+6.1	+6.6	+7.2	+7.8	+8.3	+8.9	+9.5	+10.2	12,000.
+2.2	+2.7	+3.1	+3.5	+3.9	+4.4	+4.8	+5.3	+5.7	+6.2	+6.8	+7.3	+7.9	+8.4	+9.0	15,000.
+1.9	+2.3	+2.7	+3.0	+3.4	+3.8	+4.2	+4.6	+5.0	+5.5	+6.0	+6.5	+7.0	+7.5	+8.1	18,000.
+1.1	+1.4	+1.7	+2.0	+2.3	+2.6	+2.9	+3.2	+3.5	+3.9	+4.3	+4.7	+5.2	+5.7	+6.3	24,000.
+0.2	+0.5	+0.7	+0.9	+1.1	+1.4	+1.5	+1.8	+2.0	+2.2	+2.5	+2.8	+3.1	+3.5	+3.9	30,000.

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TABLE XII–2a.—*Departures*

FOR TERRESTRIAL ARTILLERY EXCEPTING HIGH-ANGLE FIRE;

Maximum ordinate (feet)	Departures from mean density factor at surface														
	−11.0	−10.0	−9.0	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0	+3.0
600	−10.8	−9.8	−8.8	−7.8	−6.8	−5.8	−4.9	−3.9	−2.9	−1.9	−0.9	+0.1	+1.0	+2.0	+3.0
1,500	−10.5	−9.5	−8.5	−7.5	−6.6	−5.6	−4.7	−3.7	−2.7	−1.8	−0.8	+0.2	+1.1	+2.0	+2.9
3,000	−9.9	−9.0	−8.0	−7.1	−6.1	−5.2	−4.3	−3.4	−2.5	−1.5	−0.6	+0.3	+1.1	+2.0	+2.9
4,500	−9.4	−8.5	−7.6	−6.6	−5.7	−4.8	−3.9	−3.0	−2.2	−1.3	−0.4	+0.4	+1.2	+2.0	+2.8
6,000	−9.0	−8.1	−7.2	−6.3	−5.4	−4.5	−3.7	−2.8	−2.0	−1.2	−0.4	+0.4	+1.1	+1.9	+2.6
9,000	−8.4	−7.5	−6.6	−5.8	−4.9	−4.1	−3.3	−2.6	−1.8	−1.1	−0.4	+0.3	+0.9	+1.6	+2.1
12,000	−7.8	−6.9	−6.1	−5.3	−4.5	−3.8	−3.1	−2.4	−1.7	−1.1	−0.4	+0.2	+0.7	+1.3	+1.8
15,000	−7.2	−6.4	−5.6	−4.9	−4.2	−3.5	−2.9	−2.2	−1.6	−1.1	−0.5	0.0	+0.5	+1.0	+1.5
18,000	−6.7	−6.0	−5.3	−4.6	−3.9	−3.3	−2.7	−2.2	−1.6	−1.1	−0.6	−0.1	+0.3	+0.8	+1.2
24,000	−6.1	−5.4	−4.8	−4.2	−3.6	−3.1	−2.6	−2.1	−1.7	−1.2	−0.8	−0.4	−0.1	+0.3	+0.6
30,000	−5.8	−5.2	−4.6	−4.0	−3.6	−3.1	−2.7	−2.3	−1.9	−1.6	−1.3	−1.0	−0.7	−0.4	−0.2

TABLE XII–3n.—*Departures*

FOR TERRESTRIAL ARTILLERY EXCEPTING HIGH-ANGLE FIRE;

Maximum ordinate (feet)	Departures from mean density factor at surface										
	−9.0	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0
600	−9.3	−8.3	−7.3	−6.3	−5.3	−4.3	−3.3	−2.3	−1.3	−0.3	+0.7	+1.7
1,500	−9.5	−8.5	−7.5	−6.5	−5.5	−4.5	−3.5	−2.5	−1.6	−0.6	+0.4	+1.3
3,000	−9.5	−8.5	−7.5	−6.5	−5.5	−4.5	−3.6	−2.6	−1.7	−0.8	+0.1	+1.0
4,500	−9.3	−8.4	−7.4	−6.4	−5.4	−4.4	−3.5	−2.6	−1.7	−0.8	0.0	+0.8
6,000	−9.1	−8.1	−7.1	−6.2	−5.2	−4.3	−3.3	−2.5	−1.6	−0.8	0.0	+0.8
9,000	−8.4	−7.5	−6.5	−5.7	−4.8	−3.9	−3.0	−2.2	−1.4	−0.7	+0.1	+0.7
12,000	−7.7	−6.9	−6.0	−5.2	−4.4	−3.5	−2.8	−2.0	−1.3	−0.6	0.0	+0.6
15,000	−7.1	−6.3	−5.5	−4.8	−4.0	−3.3	−2.6	−1.9	−1.2	−0.6	0.0	+0.5
18,000	−6.6	−5.9	−5.2	−4.4	−3.7	−3.1	−2.4	−1.8	−1.2	−0.6	−0.1	+0.4
24,000	−6.0	−5.3	−4.7	−4.0	−3.4	−2.8	−2.3	−1.8	−1.2	−0.8	−0.3	+0.1
30,000	−5.6	−5.0	−4.4	−3.9	−3.4	−2.8	−2.4	−2.0	−1.5	−1.2	−0.8	−0.5

TABLE XII–3a.—*Departures*

FOR TERRESTRIAL ARTILLERY EXCEPTING HIGH-ANGLE FIRE;

Maximum ordinate (feet)	Departures from mean density factor at surface										
	−12.0	−11.0	−10.0	−9.0	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0
600	−11.8	−10.8	−9.8	−8.8	−7.8	−6.8	−5.8	−4.8	−3.8	−2.8	−1.9	−0.9
1,500	−11.5	−10.5	−9.5	−8.5	−7.5	−6.5	−5.5	−4.6	−3.6	−2.6	−1.7	−0.8
3,000	−11.0	−10.0	−9.0	−8.0	−7.0	−6.1	−5.1	−4.2	−3.2	−2.3	−1.4	−0.5
4,500	−10.5	−9.5	−8.5	−7.5	−6.6	−5.6	−4.6	−3.7	−2.8	−1.9	−1.1	−0.3
6,000	−10.1	−9.1	−8.1	−7.2	−6.2	−5.3	−4.3	−3.4	−2.6	−1.7	−0.9	−0.1
9,000	−9.2	−8.3	−7.4	−6.4	−5.6	−4.7	−3.8	−3.0	−2.2	−1.4	−0.7	0.0
12,000	−8.4	−7.5	−6.7	−5.9	−5.0	−4.2	−3.4	−2.7	−1.9	−1.2	−0.6	0.0
15,000	−7.7	−6.9	−6.1	−5.4	−4.6	−3.8	−3.1	−2.4	−1.7	−1.1	−0.5	0.0
18,000	−7.2	−6.4	−5.7	−5.0	−4.3	−3.6	−2.9	−2.3	−1.7	−1.1	−0.5	−0.1
24,000	−6.4	−5.8	−5.1	−4.5	−3.9	−3.3	−2.9	−2.2	−1.6	−1.1	−0.7	−0.3
30,000	−6.0	−5.4	−4.8	−4.3	−3.7	−3.2	−2.7	−2.3	−1.8	−1.5	−1.1	−0.8

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from mean ballistic density

VALID DURING AFTERNOON IN REGION 2 (MIDWESTERN U. S. A.)

Departures from mean density factor at surface—Continued														Maximum ordinate (feet)
+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	+11.0	+12.0	+13.0	+14.0	+15.0	+16.0	+17.0	+18.0	
+3.9	+4.9	+5.9	+6.8	+7.8	+8.7	+9.7	+10.7	+11.6	+12.6	+13.6	+14.6	+15.6	+16.5	+17.5	600.
+3.8	+4.8	+5.7	+6.5	+7.5	+8.3	+9.2	+10.2	+11.1	+12.0	+13.0	+13.9	+14.9	+15.8	+16.8	1,500.
+3.7	+4.5	+5.3	+6.1	+6.9	+7.7	+8.4	+9.3	+10.1	+11.0	+11.9	+12.8	+13.9	+14.6	+15.5	3,000.
+3.5	+4.2	+5.0	+5.6	+6.3	+7.0	+7.6	+8.3	+9.1	+9.9	+10.8	+11.6	+12.7	+13.4	+14.3	4,500.
+3.2	+3.9	+4.5	+5.1	+5.7	+6.3	+6.9	+7.6	+8.3	+9.1	+9.9	+10.7	+11.7	+12.4	+13.2	6,000.
+2.7	+3.3	+3.8	+4.3	+4.8	+5.4	+5.9	+6.5	+7.1	+7.7	+8.5	+9.2	+10.0	+10.6	+11.4	9,000.
+2.3	+2.8	+3.2	+3.7	+4.2	+4.7	+5.1	+5.6	+6.2	+6.8	+7.4	+8.0	+8.7	+9.3	+10.0	12,000.
+1.9	+2.3	+2.8	+3.2	+3.6	+4.0	+4.4	+4.9	+5.4	+5.9	+6.5	+7.1	+7.7	+8.3	+8.9	15,000.
+1.6	+2.0	+2.3	+2.7	+3.1	+3.5	+3.8	+4.3	+4.7	+5.2	+5.7	+6.2	+6.8	+7.4	+8.0	18,000.
+0.9	+1.2	+1.5	+1.8	+2.1	+2.4	+2.7	+3.0	+3.3	+3.7	+4.1	+4.6	+5.1	+5.6	+6.2	24,000.
+0.1	+0.3	+0.5	+0.7	+0.9	+1.2	+1.4	+1.6	+1.8	+2.0	+2.4	+2.7	+3.1	+3.4	+3.8	30,000.

from mean ballistic density

VALID DURING THE NIGHT IN REGION 3 (WESTERN U. S. A.)

Departures from mean density factor at surface—Continued												Maximum ordinate (feet)
+3.0	+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	+11.0	+12.0	+13.0	+14.0	
+2.6	+3.6	+4.6	+5.6	+6.5	+7.5	+8.5	+9.4	+10.4	+11.4	+12.3	+13.3	600.
+2.2	+3.1	+4.1	+5.0	+5.8	+6.8	+7.7	+8.5	+9.5	+10.4	+11.2	+12.2	1,500.
+1.8	+2.7	+3.5	+4.3	+5.2	+6.0	+6.8	+7.6	+8.4	+9.2	+10.0	+10.8	3,000.
+1.6	+2.4	+3.1	+3.9	+4.6	+5.3	+6.1	+6.7	+7.5	+8.2	+8.9	+9.6	4,500.
+1.5	+2.2	+2.9	+3.6	+4.2	+4.8	+5.5	+6.1	+6.7	+7.4	+8.1	+8.8	6,000.
+1.3	+1.9	+2.5	+3.0	+3.6	+4.1	+4.7	+5.2	+5.8	+6.3	+7.0	+7.6	9,000.
+1.2	+1.7	+2.2	+2.7	+3.1	+3.6	+4.1	+4.5	+5.0	+5.5	+6.1	+6.6	12,000.
+1.0	+1.4	+1.9	+2.3	+2.7	+3.1	+3.5	+4.0	+4.4	+4.8	+5.3	+5.8	15,000.
+0.8	+1.2	+1.6	+2.0	+2.4	+2.7	+3.1	+3.5	+3.8	+4.2	+4.7	+5.1	18,000.
+0.5	+0.8	+1.1	+1.4	+1.7	+2.0	+2.2	+2.4	+2.6	+2.8	+3.0	+3.3	24,000.
−0.2	+0.1	+0.3	+0.6	+0.8	+0.9	+1.1	+1.1	+1.2	+1.3	+1.3	+1.4	30,000.

from mean ballistic density

VALID DURING THE AFTERNOON IN REGION 3 (WESTERN U. S. A.)

Departures from mean density factor at surface—Continued												Maximum ordinate (feet)
0.0	+1.0	+2.0	+3.0	+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	+11.0	+12.0	
+0.1	+1.1	+2.0	+3.0	+4.0	+4.9	+5.9	+6.8	+7.8	+8.8	+9.7	+10.7	+11.7	600.
+0.2	+1.1	+2.0	+2.9	+3.9	+4.8	+5.7	+6.6	+7.5	+8.4	+9.3	+10.2	+11.2	1,500.
+0.4	+1.2	+2.0	+2.9	+3.7	+4.5	+5.3	+6.1	+6.9	+7.8	+8.6	+9.4	+10.3	3,000.
+0.5	+1.3	+2.1	+2.8	+3.5	+4.2	+5.0	+5.7	+6.4	+7.2	+7.9	+8.6	+9.4	4,500.
+0.6	+1.3	+2.0	+2.7	+3.3	+4.0	+4.6	+5.2	+5.9	+6.6	+7.2	+8.0	+8.7	6,000.
+0.7	+1.3	+1.8	+2.4	+2.9	+3.5	+4.0	+4.6	+5.1	+5.7	+6.3	+7.0	+7.6	9,000.
+0.6	+1.1	+1.7	+2.1	+2.6	+3.1	+3.6	+4.0	+4.5	+5.0	+5.5	+6.1	+6.6	12,000.
+0.5	+1.0	+1.5	+1.9	+2.3	+2.7	+3.1	+3.5	+4.0	+4.4	+4.9	+5.3	+5.8	15,000.
+0.4	+0.8	+1.3	+1.6	+2.0	+2.4	+2.7	+3.1	+3.5	+3.9	+4.3	+4.7	+5.1	18,000.
+0.1	+0.5	+0.8	+1.2	+1.4	+1.7	+2.0	+2.2	+2.4	+2.6	+2.8	+3.0	+3.3	24,000.
−0.4	−0.2	+0.1	+0.4	+0.6	+0.8	+0.9	+1.0	+1.1	+1.1	+1.2	+1.3	+1.4	30,000.

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TABLE XII-4n.—*Departures from mean ballistic density*

FOR TERRESTRIAL ARTILLERY EXCEPTING HIGH-ANGLE FIRE; VALID DURING THE NIGHT IN REGION 4 (CALIFORNIA COAST)

Maximum ordinate (feet)	Departures from mean density factor at surface												Maximum ordinate (feet)
	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0	+3.0	+4.0	+5.0	
600	−6.1	−5.1	−4.1	−3.1	−2.1	−1.1	−0.2	+0.7	+1.7	+2.6	+3.5	+4.4	600
1,500	−6.2	−5.2	−4.2	−3.2	−2.2	−1.3	−0.5	+0.4	+1.2	+1.9	+2.7	+3.4	1,500
3,000	−6.3	−5.3	−4.3	−3.4	−2.4	−1.6	−0.8	−0.1	+0.6	+1.3	+1.9	+2.4	3,000
4,500	−6.5	−5.5	−4.5	−3.6	−2.6	−1.8	−1.0	−0.3	+0.4	+0.9	+1.5	+2.0	4,500
6,000	−6.6	−5.6	−4.6	−3.7	−2.7	−1.9	−1.1	−0.4	+0.2	+0.7	+1.2	+1.8	6,000
9,000	−6.5	−5.6	−4.6	−3.7	−2.8	−2.0	−1.2	−0.6	0.0	+0.4	+0.9	+1.4	9,000
12,000	−6.1	−5.2	−4.4	−3.5	−2.7	−2.0	−1.3	−0.7	−0.2	+0.2	+0.6	+1.0	12,000
15,000	−5.6	−4.9	−4.1	−3.4	−2.6	−2.0	−1.3	−0.8	−0.3	0.0	+0.4	+0.7	15,000
18,000	−5.3	−4.6	−3.9	−3.2	−2.5	−1.9	−1.3	−0.8	−0.4	−0.1	+0.2	+0.5	18,000
24,000	−4.9	−4.3	−3.7	−3.1	−2.5	−1.9	−1.4	−0.9	−0.6	−0.4	−0.2	+0.1	24,000
30,000	−4.6	−4.1	−3.5	−3.0	−2.5	−2.0	−1.6	−1.2	−0.9	−0.8	−0.6	−0.4	30,000

TABLE XII-4a.—*Departures from mean ballistic density*

FOR TERRESTRIAL ARTILLERY EXCEPTING HIGH-ANGLE FIRE; VALID DURING THE AFTERNOON IN REGION 4 (CALIFORNIA COAST)

Maximum ordinate (feet)	Departures from mean density factor at surface											Maximum ordinate (feet)
	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0	+3.0	
600	−7.9	−6.9	−5.9	−4.9	−3.9	−2.9	−2.0	−1.0	0.0	+0.9	+1.9	+2.8	600
1,500	−7.8	−6.8	−5.8	−4.8	−3.8	−2.8	−1.9	−1.0	0.0	+0.8	+1.7	+2.5	1,500
3,000	−7.6	−6.6	−5.6	−4.6	−3.6	−2.7	−1.8	−0.9	−0.1	+0.7	+1.3	+2.0	3,000
4,500	−7.4	−6.4	−5.4	−4.4	−3.4	−2.5	−1.7	−0.9	−0.1	+0.5	+1.1	+1.7	4,500
6,000	−7.3	−6.3	−5.3	−4.3	−3.3	−2.4	−1.6	−0.9	−0.2	+0.4	+1.0	+1.5	6,000
9,000	−6.9	−6.0	−5.1	−4.1	−3.2	−2.4	−1.6	−0.9	−0.3	+0.2	+0.7	+1.2	9,000
12,000	−6.4	−5.6	−4.7	−3.9	−3.1	−2.3	−1.6	−1.0	−0.4	0.0	+0.5	+0.9	12,000
15,000	−5.9	−5.1	−4.4	−3.6	−2.9	−2.2	−1.5	−1.0	−0.5	−0.1	+0.3	+0.6	15,000
18,000	−5.5	−4.8	−4.1	−3.4	−2.8	−2.1	−1.5	−1.0	−0.6	−0.2	+0.1	+0.4	18,000
24,000	−5.1	−4.4	−3.8	−3.2	−2.6	−2.1	−1.5	−1.0	−0.7	−0.5	−0.3	0.0	24,000
30,000	−4.7	−4.2	−3.7	−3.2	−2.6	−2.1	−1.7	−1.3	−1.0	−0.8	−0.6	−0.4	30,000

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TABLE XII-5.—*Departures from*

FOR TERRESTRIAL ARTILLERY EXCEPTING HIGH

Maximum ordinate (feet)	Departures from mean density factor at surface													
	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0.0	+1.0	+2.0	+3.0	+4.0	+5.0	+6.0	+7.0
600	−5.8	−4.9	−3.9	−2.9	−2.0	−1.0	0.0	+1.0	+1.9	+2.9	+3.8	+4.8	+5.7	+6.7
1,500	−5.6	−4.7	−3.7	−2.8	−1.9	−0.9	0.0	+0.9	+1.8	+2.7	+3.6	+4.5	+5.3	+6.1
3,000	−5.2	−4.4	−3.5	−2.6	−1.7	−0.9	0.0	+0.9	+1.7	+2.5	+3.3	+4.1	+4.8	+5.4
4,500	−4.9	−4.0	−3.2	−2.4	−1.6	−0.8	+0.1	+0.9	+1.6	+2.4	+3.1	+3.8	+4.3	+4.9
6,000	−4.5	−3.7	−2.9	−2.2	−1.4	−0.6	+0.1	+0.9	+1.6	+2.3	+2.9	+3.5	+4.0	+4.5
9,000	−3.9	−3.2	−2.6	−1.9	−1.2	−0.5	+0.2	+0.8	+1.4	+2.1	+2.6	+3.1	+3.5	+3.9
12,000	−3.6	−2.9	−2.3	−1.7	−1.1	−0.5	+0.1	+0.7	+1.3	+1.8	+2.3	+2.7	+3.1	+3.4
15,000	−3.3	−2.8	−2.2	−1.6	−1.1	−0.5	0.0	+0.6	+1.1	+1.6	+2.0	+2.4	+2.7	+3.0
18,000	−3.2	−2.7	−2.2	−1.6	−1.1	−0.6	−0.1	+0.4	+0.9	+1.3	+1.7	+2.1	+2.4	+2.7
24,000	−3.0	−2.6	−2.2	−1.7	−1.3	−0.8	−0.4	0.0	+0.4	+0.7	+1.0	+1.3	+1.8	+1.8
30,000	−3.0	−2.7	−2.4	−2.1	−1.7	−1.4	−1.1	−0.8	−0.5	−0.3	0.0	+0.2	+0.4	+0.5

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ean ballistic density

NGLE FIRE; VALID IN REGION 5 (ALASKA)

Departures from mean density factor at surface—Continued															Maximum ordinate (feet)
8.0	+9.0	+10.0	+11.0	+12.0	+13.0	+14.0	+15.0	+16.0	+17.0	+18.0	+19.0	+20.0	+21.0	+22.0	
7.6	+8.5	+9.4	+10.3	+11.2	+12.1	+13.1	+14.0	+15.0	+16.0	+17.0	+18.0	+19.0	+20.0	+21.0	600.
7.0	+7.8	+8.6	+9.4	+10.3	+11.1	+11.9	+12.7	+13.6	+14.5	+15.5	+16.5	+17.5	+18.5	+19.5	1,500.
6.1	+6.7	+7.4	+8.0	+8.7	+9.3	+10.0	+10.8	+11.7	+12.6	+13.6	+14.5	+15.5	+16.5	+17.5	3,000.
5.4	+5.9	+6.5	+7.0	+7.6	+8.1	+8.7	+9.4	+10.3	+11.2	+12.1	+13.1	+14.1	+15.1	+16.1	4,500.
4.9	+5.4	+5.9	+6.3	+6.8	+7.2	+7.7	+8.4	+9.2	+10.1	+11.0	+12.0	+12.9	+13.9	+14.8	6,000.
4.2	+4.6	+4.9	+5.3	+5.7	+6.0	+6.4	+7.1	+7.8	+8.6	+9.5	+10.3	+11.2	+12.1	+13.0	9,000.
3.7	+4.0	+4.3	+4.6	+4.9	+5.2	+5.5	+6.1	+6.8	+7.5	+8.3	+9.1	+9.9	+10.7	+11.6	12,000
3.3	+3.5	+3.8	+4.0	+4.3	+4.5	+4.8	+5.3	+5.9	+6.6	+7.3	+8.1	+8.9	+9.6	+10.4	15,000.
2.9	+3.1	+3.3	+3.5	+3.8	+4.0	+4.2	+4.6	+5.2	+5.9	+6.6	+7.3	+8.0	+8.8	+9.5	18,000.
2.0	+2.2	+2.4	+2.5	+2.7	+2.9	+3.1	+3.4	+3.8	+4.4	+5.1	+5.7	+6.4	+7.1	+7.8	24,000.
0.6	+0.8	+0.9	+1.0	+1.1	+1.2	+1.4	+1.6	+2.0	+2.5	+3.1	+3.7	+4.4	+5.0	+5.6	30,000.

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TABLE XII-6n.—*Departures from mean ballistic density*

FOR TERRESTRIAL ARTILLERY EXCEPTING HIGH-ANGLE FIRE VALID DURING THE NIGHT IN REGION 6 (WEST INDIES, CANAL ZONE AND HAWAII)

Maximum ordinate (feet)	Departures from mean density factor at surface							Maximum ordinate (feet)
	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	
600	−6.9	−5.9	−4.9	−3.9	−2.9	−1.9	−0.9	600.
1,500	−6.7	−5.8	−4.8	−3.8	−2.9	−1.9	−0.9	1,500.
3,000	−6.4	−5.6	−4.6	−3.7	−2.7	−1.8	−0.9	3,000.
4,500	−6.2	−5.3	−4.4	−3.5	−2.5	−1.6	−0.7	4,500.
6,000	−6.0	−5.2	−4.2	−3.3	−2.3	−1.4	−0.5	6,000.
9,000	−5.6	−4.9	−4.0	−3.1	−2.2	−1.3	−0.4	9,000.
12,000	−5.4	−4.7	−3.9	−3.1	−2.2	−1.4	−0.6	12,000.
15,000	−5.1	−4.6	−3.8	−3.1	−2.3	−1.6	−0.8	15,000.
18,000	−5.0	−4.4	−3.8	−3.1	−2.4	−1.8	−1.1	18,000.
24,000	−4.8	−4.3	−3.7	−3.2	−2.6	−2.0	−1.5	24,000.
30,000	−4.8	−4.4	−3.8	−3.3	−2.7	−2.2	−1.7	30,000.

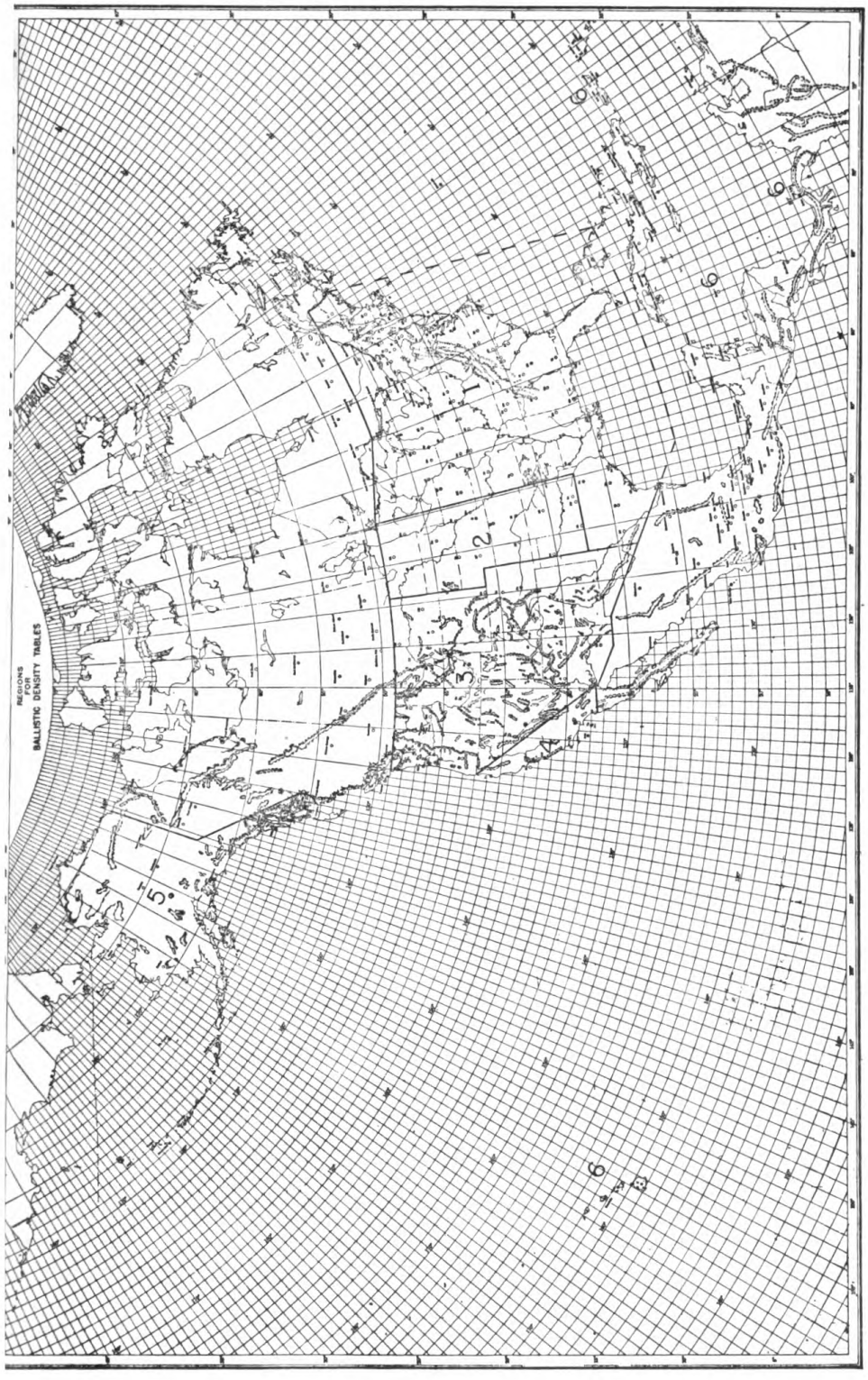
TABLE XII-6a.—*Departures from mean ballistic density*

FOR TERRESTRIAL ARTILLERY EXCEPTING HIGH-ANGLE FIRE VALID DURING THE AFTERNOON IN REGION 6 (WEST INDIES CANAL ZONE AND HAWAII)

Maximum ordinate (feet)	Departures from mean density factor at surface								Maximum ordinate (feet)
	−9.0	−8.0	−7.0	−6.0	−5.0	−4.0	−3.0	−2.0	
600	−8.8	−7.8	−6.8	−5.8	−4.8	−3.8	−2.8	−1.8	600.
1,500	−8.4	−7.5	−6.5	−5.5	−4.5	−3.5	−2.5	−1.5	1,500.
3,000	−7.8	−6.9	−6.0	−5.0	−4.1	−3.1	−2.1	−1.1	3,000.
4,500	−7.3	−6.4	−5.5	−4.5	−3.6	−2.6	−1.6	−0.6	4,500.
6,000	−6.9	−6.1	−5.2	−4.2	−3.2	−2.3	−1.3	−0.3	6,000.
9,000	−6.4	−5.6	−4.8	−3.9	−3.0	−2.0	−1.1	−0.2	9,000.
12,000	−6.0	−5.3	−4.5	−3.7	−2.9	−2.0	−1.2	−0.4	12,000.
15,000	−5.6	−5.0	−4.4	−3.6	−2.9	−2.1	−1.4	−0.6	15,000.
18,000	−5.4	−4.9	−4.3	−3.6	−2.9	−2.2	−1.6	−0.9	18,000.
24,000	−5.1	−4.6	−4.1	−3.6	−3.0	−2.4	−1.8	−1.3	24,000.
30,000	−5.1	−4.7	−4.2	−3.6	−3.1	−2.6	−2.0	−1.5	30,000.

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Chief of Staff.

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TECHNICAL MANUAL

METEOROLOGY FOR COAST ARTILLERY

CHANGES No. 2

WAR DEPARTMENT,
WASHINGTON, November 7, 1942.

TM 4-240, December 20, 1941, is changed as follows:

APPENDIX I

METEOROLOGICAL TABLES

The following is added to table VI:

TABLE VI.—*Relative humidity in percent of saturation*—Continued

Air temperature ° F.	Depression of wet-bulb thermometer in degrees F.															
	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
110	26	25	23	21	20	18	17	15	14	12	11	10	8	7	6	4
112	27	26	24	23	21	19	18	16	15	14	12	11	9	8	7	6
114	28	27	25	24	22	20	19	18	16	15	13	12	11	9	8	7
116	29	28	26	25	23	22	20	19	17	16	14	13	12	11	9	8
118	30	29	27	25	24	23	21	20	18	17	16	14	13	12	11	9
120	31	29	28	26	25	23	22	21	19	18	17	15	14	13	12	10
122	32	30	29	27	26	24	23	22	20	19	18	16	15	14	13	11
124	33	31	30	28	27	25	24	22	21	20	18	17	16	15	14	12
126	33	32	30	29	27	26	25	23	22	21	19	18	17	16	15	13
128	34	33	31	30	28	27	25	24	23	22	20	19	18	17	16	14
130	35	33	32	30	29	28	26	25	24	22	21	20	19	18	16	15
132	36	34	33	31	30	28	27	26	24	23	22	21	20	18	17	16
134	36	35	33	32	30	29	28	26	25	24	23	21	20	19	18	17
136	37	35	34	33	31	30	28	27	26	25	23	22	21	20	19	18
138	37	36	35	33	32	30	29	28	27	25	24	23	22	21	20	19
140	38	37	35	34	32	31	30	29	27	26	25	24	23	21	20	19

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The following is added to table VII:

TABLE VII.—*Air density in percent of standard when relative humidity is 78 percent*—Continued

Pressure	Temperature, degrees F.									
	104	108	112	116	120	124	128	132	136	140
27.00	82. 5	81. 7	80. 8	80. 0	79. 1	78. 2	77. 3	76. 3	75. 3	74. 3
27.10	82. 8	82. 0	81. 1	80. 3	79. 4	78. 5	77. 6	76. 6	75. 6	74. 6
27.20	83. 1	82. 3	81. 5	80. 6	79. 7	78. 8	77. 9	76. 9	75. 9	74. 9
27.30	83. 5	82. 6	81. 8	80. 9	80. 0	79. 1	78. 2	77. 2	76. 2	75. 2
27.40	83. 8	82. 9	82. 1	81. 2	80. 3	79. 4	78. 5	77. 5	76. 5	75. 5
27.50	84. 1	83. 2	82. 4	81. 5	80. 6	79. 7	78. 8	77. 8	76. 8	75. 8
27.60	84. 4	83. 6	82. 7	81. 8	80. 9	80. 0	79. 1	78. 1	77. 1	76. 1
27.70	84. 7	83. 9	83. 0	82. 1	81. 2	80. 3	79. 4	78. 4	77. 4	76. 4
27.80	85. 0	84. 2	83. 3	82. 4	81. 5	80. 6	79. 7	78. 7	77. 7	76. 7
27.90	85. 3	84. 5	83. 6	82. 7	81. 8	80. 9	80. 0	79. 0	78. 0	77. 0
28.00	85. 7	84. 8	83. 9	83. 0	82. 1	81. 2	80. 3	79. 3	78. 3	77. 3
28.10	86. 0	85. 1	84. 2	83. 3	82. 4	81. 5	80. 6	79. 6	78. 6	77. 6
28.20	86. 3	85. 4	84. 5	83. 6	82. 7	81. 8	80. 9	79. 9	78. 9	77. 9
28.30	86. 6	85. 7	84. 9	84. 0	83. 0	82. 1	81. 2	80. 2	79. 2	78. 1
28.40	86. 9	86. 0	85. 2	84. 3	83. 3	82. 4	81. 5	80. 5	79. 5	78. 4
28.50	87. 2	86. 4	85. 5	84. 6	83. 6	82. 7	81. 8	80. 8	79. 8	78. 7
28.60	87. 5	86. 7	85. 8	84. 9	84. 0	83. 0	82. 1	81. 1	80. 1	79. 0
28.70	87. 8	87. 0	86. 1	85. 2	84. 3	83. 3	82. 4	81. 4	80. 4	79. 3
28.80	88. 2	87. 3	86. 4	85. 5	84. 6	83. 6	82. 7	81. 7	80. 7	79. 6
28.90	88. 5	87. 6	86. 7	85. 8	84. 9	83. 9	83. 0	82. 0	81. 0	79. 9
29.00	88. 8	87. 9	87. 0	86. 1	85. 2	84. 2	83. 3	82. 3	81. 2	80. 2
29.10	89. 1	88. 2	87. 3	86. 4	85. 5	84. 5	83. 6	82. 6	81. 5	80. 5
29.20	89. 4	88. 5	87. 6	86. 7	85. 8	84. 8	83. 9	82. 9	81. 8	80. 8
29.30	89. 7	88. 8	87. 9	87. 0	86. 1	85. 1	84. 2	83. 2	82. 1	81. 1
29.40	90. 0	89. 1	88. 2	87. 3	86. 4	85. 4	84. 5	83. 5	82. 4	81. 4
29.50	90. 3	89. 5	88. 6	87. 6	86. 7	85. 7	84. 8	83. 8	82. 7	81. 7
29.60	90. 7	89. 8	88. 9	87. 9	87. 0	86. 0	85. 1	84. 1	83. 0	82. 0
29.70	91. 0	90. 1	89. 2	88. 2	87. 3	86. 3	85. 4	84. 4	83. 3	82. 3
29.80	91. 3	90. 4	89. 5	88. 6	87. 6	86. 6	85. 7	84. 7	83. 6	82. 6
29.90	91. 6	90. 7	89. 8	88. 9	87. 9	86. 9	86. 0	85. 0	83. 9	82. 9
30.00	91. 9	91. 0	90. 1	89. 2	88. 2	87. 2	86. 3	85. 3	84. 2	83. 1
30.10	92. 2	91. 3	90. 4	89. 5	88. 5	87. 5	86. 6	85. 6	84. 5	83. 4
30.20	92. 5	91. 6	90. 7	89. 8	88. 8	87. 8	86. 9	85. 9	84. 8	83. 7
30.30	92. 9	91. 9	91. 0	90. 1	89. 1	88. 2	87. 2	86. 1	85. 1	84. 0
30.40	93. 2	92. 3	91. 3	90. 4	89. 4	88. 5	87. 5	86. 4	85. 4	84. 3
30.50	93. 5	92. 6	91. 6	90. 7	89. 7	88. 8	87. 8	86. 7	85. 7	84. 6
30.60	93. 8	92. 9	91. 9	91. 0	90. 0	89. 1	88. 1	87. 0	86. 0	84. 9
30.70	94. 1	93. 2	92. 3	91. 3	90. 3	89. 4	88. 4	87. 3	86. 3	85. 2
30.80	94. 4	93. 5	92. 6	91. 6	90. 6	89. 7	88. 7	87. 6	86. 6	85. 5
30.90	94. 7	93. 8	92. 9	91. 9	91. 0	90. 0	89. 0	87. 9	86. 9	85. 8
31.00	95. 0	94. 1	93. 2	92. 2	91. 3	90. 3	89. 3	88. 2	87. 2	86. 1

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The following is added to table VIII:

TABLE VIII.—*Air density corrections to be applied to table VII when relative humidity is other than 78 percent*—Continued

Relative humidity	Temperature, degrees F.			
	110	120	130	140
----------	+2.4	+3.1	+4.0	+5.1
----------	+2.1	+2.7	+3.5	+4.5
----------	+1.8	+2.3	+3.0	+3.8
----------	+1.5	+1.9	+2.5	+3.1
----------	+1.2	+1.5	+1.9	+2.5
----------	+0.9	+1.1	+1.4	+1.8
----------	+0.5	+0.7	+0.9	+1.2
----------	+0.2	+0.3	+0.4	+0.5
----------	−0.1	−0.1	−0.1	−0.1
----------	−0.4	−0.5	−0.6	−0.8
----------	−0.7	−0.9	−1.1	−1.4

[A. G. 062.11 (10-16-42).] (C 2, Nov. 7, 1942.)

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Chief of Staff.

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TECHNICAL MANUAL

METEOROLOGY FOR COAST ARTILLERY

CHANGES No. 3

WAR DEPARTMENT,
WASHINGTON, March 29, 1943.

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TM 4-240, December 20, 1941, is changed as follows:

APPENDIX I

METEOROLOGICAL TABLES

The following is added at the beginning of table VII:

TABLE VII.—*Air density in percent of standard when relative humidity is 78 percent*

Pressure	Temperature, degrees F.										
	−20	−16	−12	−8	−4	0	4	8	12	16	20
12.00	88. 3	87. 5	86. 7	86. 0	85. 2	84. 4	83. 7	83. 0	82. 3	81. 6	80. 8
12.10	88. 7	87. 9	87. 1	86. 4	85. 6	84. 8	84. 1	83. 4	82. 6	81. 9	81. 2
12.20	89. 1	88. 3	87. 5	86. 7	86. 0	85. 2	84. 5	83. 7	83. 0	82. 3	81. 6
12.30	89. 5	88. 7	87. 9	87. 1	86. 4	85. 6	84. 9	84. 1	83. 4	82. 7	82. 0
12.40	89. 9	89. 1	88. 3	87. 5	86. 8	86. 0	85. 2	84. 5	83. 8	83. 0	82. 3
12.50	90. 3	89. 5	88. 7	87. 9	87. 1	86. 4	85. 6	84. 9	84. 1	83. 4	82. 7
12.60	90. 7	89. 9	89. 1	88. 3	87. 5	86. 8	86. 0	85. 2	84. 5	83. 8	83. 1
12.70	91. 1	90. 3	89. 5	88. 7	87. 9	87. 1	86. 4	85. 6	84. 9	84. 2	83. 4
12.80	91. 5	90. 7	89. 9	89. 1	88. 3	87. 5	86. 8	86. 0	85. 3	84. 5	83. 8
12.90	91. 9	91. 1	90. 3	89. 5	88. 7	87. 9	87. 1	86. 4	85. 6	84. 9	84. 2
13.00	92. 3	91. 5	90. 7	89. 9	89. 1	88. 3	87. 5	86. 8	86. 0	85. 3	84. 5
13.10	92. 7	91. 9	91. 1	90. 3	89. 5	88. 7	87. 9	87. 1	86. 4	85. 6	84. 9
13.20	93. 1	92. 3	91. 5	90. 7	89. 8	89. 1	88. 3	87. 5	86. 8	86. 0	85. 3
13.30	93. 6	92. 7	91. 9	91. 0	90. 2	89. 4	88. 7	87. 9	87. 1	86. 4	85. 6
13.40	94. 0	93. 1	92. 3	91. 4	90. 6	89. 8	89. 0	88. 3	87. 5	86. 7	86. 0
13.50	94. 4	93. 5	92. 7	91. 8	91. 0	90. 2	89. 4	88. 6	87. 9	87. 1	86. 4
13.60	94. 8	93. 9	93. 0	92. 2	91. 4	90. 6	89. 8	89. 0	88. 3	87. 5	86. 7
13.70	95. 2	94. 3	93. 4	92. 6	91. 8	91. 0	90. 2	89. 4	88. 6	87. 9	87. 1
13.80	95. 6	94. 7	93. 8	93. 0	92. 2	91. 4	90. 6	89. 8	89. 0	88. 2	87. 5
13.90	96. 0	95. 1	94. 2	93. 4	92. 6	91. 7	90. 9	90. 2	89. 4	88. 6	87. 8
14.00	96. 4	95. 5	94. 6	93. 8	92. 9	92. 1	91. 3	90. 5	89. 7	89. 0	88. 2
14.10	96. 8	95. 9	95. 0	94. 2	93. 3	92. 5	91. 7	90. 9	90. 1	89. 3	88. 6
14.20	97. 2	96. 3	95. 4	94. 6	93. 7	92. 9	92. 1	91. 3	90. 5	89. 7	88. 9
14.30	97. 6	96. 7	95. 8	95. 0	94. 1	93. 3	92. 5	91. 7	90. 9	90. 1	89. 3
14.40	98. 0	97. 1	96. 2	95. 3	94. 5	93. 7	92. 8	92. 0	91. 2	90. 5	89. 7
14.50	98. 4	97. 5	96. 6	95. 7	94. 9	94. 1	93. 2	92. 4	91. 6	90. 8	90. 0
14.60	98. 8	97. 9	97. 0	96. 1	95. 3	94. 4	93. 6	92. 8	92. 0	91. 2	90. 4
14.70	99. 2	98. 3	97. 4	96. 5	95. 7	94. 8	94. 0	93. 2	92. 4	91. 6	90. 8
14.80	99. 6	98. 7	97. 8	96. 9	96. 0	95. 2	94. 4	93. 5	92. 7	91. 9	91. 2
14.90	100. 0	99. 1	98. 2	97. 3	96. 4	95. 6	94. 8	93. 9	93. 1	92. 3	91. 5
15.00	100. 4	99. 5	98. 6	97. 7	96. 8	96. 0	95. 1	94. 3	93. 5	92. 7	91. 9
15.10	100. 8	99. 9	99. 0	98. 1	97. 2	96. 4	95. 5	94. 7	93. 9	93. 1	92. 3
15.20	101. 2	100. 3	99. 4	98. 5	97. 6	96. 7	95. 9	95. 1	94. 2	93. 4	92. 6
15.30	101. 6	100. 7	99. 8	98. 9	98. 0	97. 1	96. 3	95. 4	94. 6	93. 8	93. 0
15.40	102. 0	101. 1	100. 1	99. 3	98. 4	97. 5	96. 7	95. 8	95. 0	94. 2	93. 4

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TABLE VII.—*Air density in percent of standard when relative humidity is 78 percent*—Continued

Pressure	Temperature, degrees F.										
	−20	−16	−12	−8	−4	0	4	8	12	16	20
25.50	102. 4	101. 5	100. 5	99. 6	98. 8	97. 9	97. 0	96. 2	95. 4	94. 5	93. 7
25.60	102. 8	101. 9	100. 9	100. 0	99. 1	98. 3	97. 4	96. 6	95. 7	94. 9	94. 1
25.70	103. 2	102. 3	101. 3	100. 4	99. 5	98. 7	97. 8	96. 9	96. 1	95. 3	94. 5
25.80	103. 6	102. 7	101. 7	100. 8	99. 9	99. 0	98. 2	97. 3	96. 5	95. 7	94. 8
25.90	104. 0	103. 1	102. 1	101. 2	100. 3	99. 4	98. 6	97. 7	96. 9	96. 0	95. 2
26.00	104. 4	103. 5	102. 5	101. 6	100. 7	99. 8	98. 9	98. 1	97. 2	96. 4	95. 6
26.10	104. 8	103. 8	102. 9	102. 0	101. 1	100. 2	99. 3	98. 5	97. 6	96. 8	95. 9
26.20	105. 2	104. 2	103. 3	102. 4	101. 5	100. 6	99. 7	98. 8	98. 0	97. 1	96. 3
26.30	105. 6	104. 6	103. 7	102. 8	101. 9	101. 0	100. 1	99. 2	98. 4	97. 5	96. 7
26.40	106. 0	105. 0	104. 1	103. 2	102. 2	101. 3	100. 5	99. 6	98. 7	97. 9	97. 0
26.50	106. 4	105. 4	104. 5	103. 6	102. 6	101. 7	100. 8	100. 0	99. 1	98. 3	97. 4
26.60	106. 8	105. 8	104. 9	103. 9	103. 0	102. 1	101. 2	100. 3	99. 5	98. 6	97. 8
26.70	107. 2	106. 2	105. 3	104. 3	103. 4	102. 5	101. 6	100. 7	99. 9	99. 0	98. 1
26.80	107. 6	106. 6	105. 7	104. 7	103. 8	102. 9	102. 0	101. 1	100. 2	99. 4	98. 5
26.90	108. 0	107. 0	106. 1	105. 1	104. 2	103. 3	102. 4	101. 5	100. 6	99. 7	98. 9

Pressure	Temperature, degrees F.									
	24	28	32	36	40	44	48	52	56	60
22.00	80. 2	79. 5	78. 8	78. 1	77. 5	76. 8	76. 1	75. 5	74. 8	74. 2
22.10	80. 5	79. 8	79. 2	78. 5	77. 8	77. 1	76. 5	75. 8	75. 2	74. 5
22.20	80. 9	80. 2	79. 5	78. 8	78. 2	77. 5	76. 8	76. 2	75. 5	74. 9
22.30	81. 3	80. 6	79. 9	79. 2	78. 5	77. 8	77. 2	76. 5	75. 9	75. 2
22.40	81. 6	80. 9	80. 2	79. 5	78. 9	78. 2	77. 5	76. 9	76. 2	75. 6
22.50	82. 0	81. 3	80. 6	79. 9	79. 2	78. 5	77. 9	77. 2	76. 6	75. 9
22.60	82. 3	81. 6	80. 9	80. 3	79. 6	78. 9	78. 2	77. 6	76. 9	76. 2
22.70	82. 7	82. 0	81. 3	80. 6	79. 9	79. 2	78. 6	77. 9	77. 2	76. 6
22.80	83. 1	82. 4	81. 7	81. 0	80. 3	79. 6	78. 9	78. 3	77. 6	76. 9
22.90	83. 4	82. 7	82. 0	81. 3	80. 6	80. 0	79. 3	78. 6	77. 9	77. 3
23.00	83. 8	83. 1	82. 4	81. 7	81. 0	80. 3	79. 6	78. 9	78. 3	77. 6
23.10	84. 2	83. 4	82. 7	82. 0	81. 3	80. 7	80. 0	79. 3	78. 6	77. 9
23.20	84. 5	83. 8	83. 1	82. 4	81. 7	81. 0	80. 3	79. 6	78. 9	78. 3
23.30	84. 9	84. 2	83. 5	82. 7	82. 0	81. 4	80. 7	80. 0	79. 3	78. 6
23.40	85. 3	84. 5	83. 8	83. 1	82. 4	81. 7	81. 0	80. 3	79. 6	79. 0
23.50	85. 6	84. 9	84. 2	83. 5	82. 8	82. 1	81. 4	80. 7	80. 0	79. 3
23.60	86. 0	85. 3	84. 5	83. 8	83. 1	82. 4	81. 7	81. 0	80. 3	79. 6
23.70	86. 4	85. 6	84. 9	84. 2	83. 5	82. 8	82. 1	81. 4	80. 7	80. 0
23.80	86. 7	86. 0	85. 3	84. 5	83. 8	83. 1	82. 4	81. 7	81. 0	80. 3
23.90	87. 1	86. 3	85. 6	84. 9	84. 2	83. 5	82. 8	82. 0	81. 3	80. 6
24.00	87. 5	86. 7	86. 0	85. 2	84. 5	83. 8	83. 1	82. 4	81. 7	81. 0
24.10	87. 8	87. 1	86. 3	85. 6	84. 9	84. 2	83. 4	82. 7	82. 0	81. 3
24.20	88. 2	87. 4	86. 7	86. 0	85. 2	84. 5	83. 8	83. 1	82. 4	81. 7
24.30	88. 5	87. 8	87. 0	86. 3	85. 6	84. 9	84. 1	83. 4	82. 7	82. 0
24.40	88. 9	88. 2	87. 4	86. 7	85. 9	85. 2	84. 5	83. 8	83. 1	82. 3
24.50	89. 3	88. 5	87. 8	87. 0	86. 3	85. 6	84. 8	84. 1	83. 4	82. 7
24.60	89. 6	88. 9	88. 1	87. 4	86. 6	85. 9	85. 2	84. 5	83. 7	83. 0
24.70	90. 0	89. 2	88. 5	87. 7	87. 0	86. 3	85. 5	84. 8	84. 1	83. 4
24.80	90. 4	89. 6	88. 8	88. 1	87. 3	86. 6	85. 9	85. 2	84. 4	83. 7
24.90	90. 7	90. 0	89. 2	88. 4	87. 7	87. 0	86. 2	85. 5	84. 8	84. 0

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TABLE VII.—*Air density in percent of standard when relative humidity is 78 percent*—Continued

Pressure	Temperature, degrees F.									
	24	28	32	36	40	44	48	52	56	60
25.00	91. 1	90. 3	89. 6	88. 8	88. 0	87. 3	86. 6	85. 8	85. 1	84. 4
25.10	91. 5	90. 7	89. 9	89. 2	88. 4	87. 7	86. 9	86. 2	85. 5	84. 7
25.20	91. 8	91. 1	90. 3	89. 5	88. 8	88. 0	87. 3	86. 5	85. 8	85. 1
25.30	92. 2	91. 4	90. 6	89. 9	89. 1	88. 4	87. 6	86. 9	86. 1	85. 4
25.40	92. 6	91. 8	91. 0	90. 2	89. 5	88. 7	88. 0	87. 2	86. 5	85. 7
25.50	92. 9	92. 1	91. 4	90. 6	89. 8	89. 1	88. 3	87. 6	86. 8	86. 1
25.60	93. 3	92. 5	91. 7	90. 9	90. 2	89. 4	88. 7	87. 9	87. 2	86. 4
25.70	93. 7	92. 9	92. 1	91. 3	90. 5	89. 8	89. 0	88. 3	87. 5	86. 8
25.80	94. 0	93. 2	92. 4	91. 6	90. 9	90. 1	89. 4	88. 6	87. 8	87. 1
25.90	94. 4	93. 6	92. 8	92. 0	91. 2	90. 5	89. 7	88. 9	88. 2	87. 4
26.00	94. 8	93. 9	93. 2	92. 4	91. 6	90. 8	90. 1	89. 3	88. 5	87. 8
26.10	95. 1	94. 3	93. 5	92. 7	91. 9	91. 2	90. 4	89. 6	88. 9	88. 1
26.20	95. 5	94. 7	93. 9	93. 1	92. 3	91. 5	90. 7	90. 0	89. 2	88. 5
26.30	95. 8	95. 0	94. 2	93. 4	92. 6	91. 9	91. 1	90. 3	89. 6	88. 8
26.40	96. 2	95. 4	94. 6	93. 8	93. 0	92. 2	91. 4	90. 7	89. 9	89. 1
26.50	96. 6	95. 8	94. 9	94. 1	93. 3	92. 6	91. 8	91. 0	90. 2	89. 5
26.60	96. 9	96. 1	95. 3	94. 5	93. 7	92. 9	92. 1	91. 4	90. 6	89. 8
26.70	97. 3	96. 5	95. 7	94. 9	94. 1	93. 3	92. 5	91. 7	90. 9	90. 2
26.80	97. 7	96. 8	96. 0	95. 2	94. 4	93. 6	92. 8	92. 1	91. 3	90. 5
26.90	98. 0	97. 2	96. 4	95. 6	94. 8	94. 0	93. 2	92. 4	91. 6	90. 8

Pressure	Temperature, degrees F.									
	64	68	72	76	80	84	88	92	96	100
22.00	73. 5	72. 9	72. 3	71. 6	70. 9	70. 3	69. 6	68. 9	68. 3	67. 6
22.10	73. 9	73. 2	72. 6	71. 9	71. 3	70. 6	69. 9	69. 3	68. 6	67. 9
22.20	74. 2	73. 6	72. 9	72. 3	71. 6	70. 9	70. 3	69. 6	68. 9	68. 2
22.30	74. 6	73. 9	73. 2	72. 6	71. 9	71. 3	70. 6	69. 9	69. 2	68. 5
22.40	74. 9	74. 2	73. 6	72. 9	72. 2	71. 6	70. 9	70. 2	69. 5	68. 8
22.50	75. 2	74. 6	73. 9	73. 2	72. 6	71. 9	71. 2	70. 5	69. 9	69. 1
22.60	75. 6	74. 9	74. 2	73. 6	72. 9	72. 2	71. 6	70. 9	70. 2	69. 5
22.70	75. 9	75. 2	74. 6	73. 9	73. 2	72. 6	71. 9	71. 2	70. 5	69. 8
22.80	76. 2	75. 6	74. 9	74. 2	73. 6	72. 9	72. 2	71. 5	70. 8	70. 1
22.90	76. 6	75. 9	75. 2	74. 6	73. 9	73. 2	72. 5	71. 8	71. 1	70. 4
23.00	76. 9	76. 2	75. 6	74. 9	74. 2	73. 5	72. 8	72. 1	71. 4	70. 7
23.10	77. 3	76. 6	75. 9	75. 2	74. 5	73. 9	73. 2	72. 5	71. 8	71. 0
23.20	77. 6	76. 9	76. 2	75. 6	74. 9	74. 2	73. 5	72. 8	72. 1	71. 4
23.30	77. 9	77. 2	76. 6	75. 9	75. 2	74. 5	73. 8	73. 1	72. 4	71. 7
23.40	78. 3	77. 6	76. 9	76. 2	75. 5	74. 8	74. 1	73. 4	72. 7	72. 0
23.50	78. 6	77. 9	77. 2	76. 5	75. 8	75. 2	74. 5	73. 7	73. 0	72. 3
23.60	78. 9	78. 3	77. 6	76. 9	76. 2	75. 5	74. 8	74. 1	73. 3	72. 6
23.70	79. 3	78. 6	77. 9	77. 2	76. 5	75. 8	75. 1	74. 4	73. 7	72. 9
23.80	79. 6	78. 9	78. 2	77. 5	76. 8	76. 1	75. 4	74. 7	74. 0	73. 2
23.90	80. 0	79. 3	78. 6	77. 9	77. 2	76. 5	75. 7	75. 0	74. 3	73. 6
24. 00	80. 3	79. 6	78. 9	78. 2	77. 5	76. 8	76. 1	75. 3	74. 6	73. 9
24. 10	80. 6	79. 9	79. 2	78. 5	77. 8	77. 1	76. 4	75. 7	74. 9	74. 2
24. 20	81. 0	80. 3	79. 6	78. 8	78. 1	77. 4	76. 7	76. 0	75. 2	74. 5
24. 30	81. 3	80. 6	79. 9	79. 2	78. 5	77. 8	77. 0	76. 3	75. 6	74. 8
24. 40	81. 6	80. 9	80. 2	79. 5	78. 8	78. 1	77. 4	76. 6	75. 9	75. 1

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TABLE VII.—*Air density in percent of standard when relative humidity is 78 percent*—Continued

Pressure	Temperature, degrees F.									
	64	68	72	76	80	84	88	92	96	100
4. 50	82. 0	81. 3	80. 6	79. 8	79. 1	78. 4	77. 7	76. 9	76. 2	75. 4
4. 60	82. 3	81. 6	80. 9	80. 2	79. 4	78. 7	78. 0	77. 3	76. 5	75. 8
4. 70	82. 6	81. 9	81. 2	80. 5	79. 8	79. 1	78. 3	77. 6	76. 8	76. 1
4. 80	83. 0	82. 3	81. 5	80. 8	80. 1	79. 4	78. 6	77. 9	77. 2	76. 4
4. 90	83. 3	82. 6	81. 9	81. 2	80. 4	79. 7	79. 0	78. 2	77. 5	76. 7
5. 00	83. 7	82. 9	82. 2	81. 5	80. 8	80. 0	79. 3	78. 5	77. 8	77. 0
5. 10	84. 0	83. 3	82. 5	81. 8	81. 1	80. 3	79. 6	78. 9	78. 1	77. 3
5. 20	84. 3	83. 6	82. 9	82. 1	81. 4	80. 7	79. 9	79. 2	78. 4	77. 7
5. 30	84. 7	83. 9	83. 2	82. 5	81. 7	81. 0	80. 3	79. 5	78. 7	78. 0
5. 40	85. 0	84. 3	83. 5	82. 8	82. 1	81. 3	80. 6	79. 8	79. 1	78. 3
5. 50	85. 3	84. 6	83. 9	83. 1	82. 4	81. 6	80. 9	80. 1	79. 4	78. 6
5. 60	85. 7	84. 9	84. 2	83. 5	82. 7	82. 0	81. 2	80. 5	79. 7	78. 9
5. 70	86. 0	85. 3	84. 5	83. 8	83. 0	82. 3	81. 5	80. 8	80. 0	79. 2
5. 80	86. 4	85. 6	84. 9	84. 1	83. 4	82. 6	81. 9	81. 1	80. 3	79. 5
5. 90	86. 7	85. 9	85. 2	84. 5	83. 7	82. 9	82. 2	81. 4	80. 6	79. 9
6. 00	87. 0	86. 3	85. 5	84. 8	84. 0	83. 3	82. 5	81. 7	81. 0	80. 2
6. 10	87. 4	86. 6	85. 9	85. 1	84. 3	83. 6	82. 8	82. 1	81. 3	80. 5
6. 20	87. 7	86. 9	86. 2	85. 4	84. 7	83. 9	83. 2	82. 4	81. 6	80. 8
6. 30	88. 0	87. 3	86. 5	85. 8	85. 0	84. 2	83. 5	82. 7	81. 9	81. 1
6. 40	88. 4	87. 6	86. 9	86. 1	85. 3	84. 6	83. 8	83. 0	82. 2	81. 4
6. 50	88. 7	88. 0	87. 2	86. 4	85. 7	84. 9	84. 1	83. 3	82. 6	81. 8
6. 60	89. 1	88. 3	87. 5	86. 8	86. 0	85. 2	84. 4	83. 7	82. 9	82. 1
6. 70	89. 4	88. 6	87. 9	87. 1	86. 3	85. 5	84. 8	84. 0	83. 2	82. 4
6. 80	89. 7	89. 0	88. 2	87. 4	86. 6	85. 9	85. 1	84. 3	83. 5	82. 7
6. 90	90. 1	89. 3	88. 5	87. 7	87. 0	86. 2	85. 4	84. 6	83. 8	83. 0

[A. G. 062.11 (3-9-43).] (C 3, Mar. 29, 1943.)

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

J. A. ULIO,
Major General,
The Adjutant General.

U. S. GOVERNMENT PRINTING OFFICE: 1943

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TECHNICAL MANUAL

METEOROLOGY FOR COAST ARTILLERY

CHANGES No. 4

WAR DEPARTMENT,
WASHINGTON 25, D. C., 17 September 1943.

TM 4-240, 20 December 1941, is changed as follows:

Figure 10 is changed as follows: The three plotted straight lines labeled 1500, 3000, and 4500 feet are changed to **3000, 4500,** and **6000** feet, respectively.

[A. G. 300.7 (21 Aug 43).] (C 4, 17 Sep 43.)

21. Determining ballistic winds.

* * * * * * *

b. As a partial illustrative example, the ballistic winds tabulated below were determined from the data appearing in paragraph 18*b*.

Standard altitude No.	Height in feet	Ballistic winds			
		For high-angle fire		For low-angle fire	
		Direction (mils)	Speed (mph)	Direction (mils)	Speed (mph)
3	3, 000	3, 800	8	3, 900	10
4	4, 500	4, 000	13	4, 100	18
5	6, 000	4, 200	17	4, 300	22

* * * * * * *

[A. G. 300.7 (21 Aug 43).] (C 4, 17 Sep 43.)

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SECTION VIII (ADDED)

DETERMINATION OF METEOROLOGICAL MESSAGE FOR ANTIAIRCRAFT GUNS, SIMPLIFIED METHOD

32. Purpose and scope.—*a.* The simplified method described below of determining ballistic winds for the use of antiaircraft artillery will replace the present standard method wherever it is practicable to do so.

b. Under service conditions the use of plotting boards to obtain ballistic data for antiaircraft fire is too unwieldy. The method is sufficiently accurate, but requires heavy, bulky equipment and highly trained personnel. Also, unless the section is exceptionally well trained, the method is very slow.

c. The short procedure herein described requires so little computation that data may be computed as the balloon rises and produces a finished meteorological message within seconds of the last reading on the balloon. No plotting equipment is necessary and because of the simplicity, mistakes are less likely to occur. Three men instead of four are required to man the meteorological section. In an emergency, two men can successfully perform the job.

33. Assumptions and principles of the short procedure.—*a.* The wind weighting factors given in table I are very nearly proportional to the time of ascension of the balloon to the altitude zone (counting only about one-half of the highest zone involved for every standard altitude). This system is based on factors exactly proportional to the balloon ascension times.

b. A shell is affected by the different zone winds in the same manner that the balloon is affected during its ascent. Therefore, it is no longer necessary to analyze the balloon track to obtain zone winds or to synthesize the zone winds to obtain the ballistic winds. For any standard altitude the ballistic wind may be found directly by—

(1) Obtaining the horizontal distance of the balloon from point of release at a "representative time" when the altitude of the balloon is the same as the altitude to the middle of the highest zone below the standard altitude under consideration.

(2) Dividing this distance by the time elapsed since the balloon was released. By standard altitude is meant the upper limit of the zone under consideration.

34. Equipment.—The equipment listed is that necessary for most efficient operation of the meteorological section.

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a. Equipment and supplies.	*Quantity*
Barometer ML–9	1
Cock ML–56	1
Coupling ML–49	1
Hose ML–81	1
Psychrometer ML–24	1
Watch, wrist (ordnance)	1
Observing instrument (Theodolite ML–47, BC Scope, or director)	1

b. Expendable supplies.

TM 4–240.
Forms (see figs. 11 and 12) (prepared locally).
Balloons, ML–50, ML–51, ML–64.
Candle, ML–90.
Hydrogen gas (compressed in cylinders).
Lantern, ML–91.
Rubber bands, No. 16 and No. 18.
Wicks for wet-bulb thermometer.
Miscellaneous supplies (pencils, erasers, etc.).

35. Duties of personnel.—The meteorological station is operated normally by three enlisted men. Each man is trained to perform all routine duties. In emergencies, two well trained men can successfully man the station. Routine duties are as follows:

a. Observer.—Sets up and orients the theodolite, observes the ascension of the balloon through the theodolite, and replaces the theodolite in its box at the completion of his duties.

b. Reader.—Inflates the balloon, releases the balloon at the proper time, reads the azimuth and elevation of the balloon at 1-minute intervals during the ascension, and transmits these data to the calculator.

c. Calculator.—Makes the surface observations, reduces surface data to proper form, determines the ballistic data in proper form, determines ballistic winds for each standard altitude from information submitted by reader, and prepares and dispatches the meteorological message.

36. Steps in preparing meteorological message.—The observation (theodolite) station having been located and the necessary data for orienting the observation instrument (theodolite) being on hand, the preparation of the meteorological message may be divided into the operations as listed below:

a. To determine the ballistic wind for each altitude zone—

(1) Set up and orient the theodolite.
(2) Inflate and weigh the balloon.
(3) Track the free balloon in azimuth and elevation.

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(4) From the information procured from the tracking of the balloon, determine by means of the tables on the forms (figs. 11 and 12), the ballistic wind (azimuth and speed) *as the balloon is being tracked.*

b. Make the surface observations. Determine—

(1) Air temperature.

(2) Atmospheric pressure.

(3) Relative humidity.

(4) Surface air density.

(5) The surface wind—assumed to be the same as the ballistic wind for the first standard altitude.

c. Determine the ballistic densities for each standard altitude.

d. Encode the meteorological message and dispatch the message.

37. Procedure.—*a.* In actual field practice, the surface observations are made by the calculator at the same time that the reader is connecting the field phone and inflating the balloon and the observer is setting up and orienting the theodolite.

b. When these steps are performed, the reader releases the balloon at the proper time, starts the stop watch (or notes the time, if a wrist watch is used), and assists the observer in picking up and starting to track the balloon.

c. The observer tracks the balloon in elevation and azimuth and the reader calls off the readings of elevation and azimuth at 1-minute intervals to the calculator for the duration of the tracking.

d. With practice, the calculator is able to compute surface data and densities by the time the balloon is released. The calculator enters on a previously prepared form (figs. 11 and 12) the information given him by the reader.

38. Tables.—The calculator makes use of one of two forms combined with the necessary tables. These forms with tables are shown in figures 11 and 12. The only difference between these two forms is that figure 11 is entered with angles of elevation in mils and the form in figure 12 is used with angles of elevation in degrees. These forms are divided into 15 columns; at the lower right of each form is a recording square for the meteorological message and surface data. A detailed discussion of these forms is taken up below with illustrative examples.

a. Column 1, minutes.—This column is numbered in minutes beginning with 1 and ending with 50. Readings begin with the first minute and continue as long as desired.

b. Column 2, elevation angle (degrees or mils).—Filled in by calculator from values given him by the reader. Only those readings that correspond to zone numbers in column 4 are necessary. However, other readings next to them are desirable for checks.

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c. Column 3, azimuth angle from north.—Filled in by calculator from values given him by reader. Only those readings that correspond to zone numbers in column 4 are necessary. However, other readings next to them are desirable for check.

d. Column 4, zone.—This column indicates the zone in which the balloon is located at each minute of its ascension shown in column 1.

e. Columns 5–9, ballistic wind speed table.—(1) From these columns is figured the ballistic wind speed. As soon as the data for a zone are read, the part of the meteorological message pertaining to that zone can be immediately filled in as described below.

(*a*) Using the elevation angle from column 2 for the zone concerned, enter one of the columns 5 to 8, depending upon the zone being considered. Find in the column the numbers which bracket the measured elevation angle. Opposite these two bracketing numbers in the actual interval between them, read in column 9 the speed of the ballistic wind in miles per hour for that zone. Enter this speed in empty columns 3 and 4 of the meteorological message, in the lower right-hand corner of the forms.

(*b*) *Example:* At 4 minutes of ascension the angular elevation of the balloon is 48.1°. Using figure 12, the degree tables, read opposite 4 minutes in column 1 to zone column in column 4, and read zone 3 which corresponds to this time of ascension. Entering the Ballistic Wind Speed Table column 6 (headed "Zones 2 or 3") with the elevation 48.1°, the two bracketing numbers are 49.9° and 45.8. In the interval between them in column 9, the speed is found to be 7 miles per hour.

NOTE.—If the elevation reading is the same as a figure in the Ballistic Wind Speed Table, use the highest indicated wind speed.

Example: At the 12th minute of ascension the elevation of the balloon is 43.0°. Using the column 8 (over zone 5), we find 43.0° in the table. Either 7 mph or 8 mph is indicated. Therefore, the highest indicated wind speed, 8 mph, is selected.

(2) Elevation angle in mils. If the observed elevation angle is in mils, follow the same procedure using the table in figure 11.

f. Columns 10–15, ballistic wind direction.—The ballistic wind direction is the direction *from* which the wind is blowing.

(1) For azimuth in mils, for meteorological purposes it is considered that the ballistic wind direction measured to the nearest hundred mils is sufficiently accurate. Therefore, enter one of the columns marked azimuth in figure 11, with the azimuth angle from column 3, using the one to the nearest hundred mils and read the direction of the ballistic wind in the right adjacent columns.

(2) For azimuth in degrees, use the form in figure 12, figured for readings in degrees. For the final meteorological message the ballistic

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wind direction is expressed in mils. The ballistic wind direction table of figure 12 is entered into with the actual azimuth angles in degrees and furnishes the ballistic wind direction in mils. To use this table, find the two numbers in the azimuth column between which the observed balloon azimuth lies. The direction *from* which the wind is blowing, expressed to the nearest hundred mils, is found in the direction column on the right, the value in mils being between the two bracketing azimuths.

Example: The observed balloon azimuth is 49.5°. The two bracketing azimuths are found in column 10 and are 47.8° and 53.4°. In the right-hand "direction" column, column 11, in the interval between these two bracketing azimuths is read the ballistic wind direction in hundredths of mils, 41, or 4,100 mils.

NOTE.—If the balloon azimuth corresponds to a reading in the balloon azimuth column of the table, use the higher wind direction indicated.

(3) The rest of the meteorological message and the surface data are filled in as normally.

39. Methods employed without full equipment.—*a.* It will be noticed that in the list of equipment (par. 34) several standard items of equipment listed in table XIII have been omitted. The plotting equipment is not necessary when this system is used. As the meteorological section all can work near or at the observing instrument, no intersection communications are listed. Also the timing device is not necessary due to the section being together, although it will be convenient if available.

b. The theodolite is the standard meteorological observing instrument. Under field conditions it has been found that the directors M4 and M7 may be used (with power) or a transit with prismatic eyepiece may be used satisfactorily. In emergencies other instruments such as a BC scope may be used.

c. In case the cock ML-56 is misplaced, an approximate measure of the amount of gas to put in the balloon may be found by remembering that the average balloon measures 25 inches in diameter if properly inflated. However, variations in individual balloons make this a very rough measure, and its use should not be encouraged. If means of weighing accurately are available, a weight equal to that of the cock ML-56 may be made (4.66 ounces) and used to measure the lift of the inflated balloon.

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METEOROLOGICAL DATA SHEET, SIMPLIFIED METHOD, FOR ANTIAIRCRAFT ONLY

Aseension				Ballistic wind speed					Ballistic wind direction					
				Enter with elevation					Enter with azimuth angle					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Minute	Elevation angle (mils)	Azimuth angle (mils) from North	Zone	Zone 1	Zones 2 and 3	Zones 4 and 5	Over 5 zones	Speed	Azimuth	Direction	Azimuth	Direction	Azimuth	Direction
				1600	1600	1600	1600		0	3200	2100	5300	4200	1000
1			1	1538	1534	1531	1527	0	100	3300	2200	5400	4300	1100
2			2	1415	1404	1394	1385	1	200	3400	2300	5500	4400	1200
3				1298	1281	1265	1251	2	300	3500	2400	5600	4500	1300
4			3	1188	1166	1146	1128	3	400	3600	2500	5700	4600	1400
5				1088	1062	1039	1018	4	500	3700	2600	5800	4700	1500
6			4	997	969	944	922	5	600	3800	2700	5900	4800	1600
7				916	887	860	838	6	700	3900	2800	6000	4900	1700
8			5	844	814	788	765	7	800	4000	2900	6100	5000	1800
9				781	759	724	702	8	900	4100	3000	6200	5100	1900
10				724	695	669	647	9	1000	4200	3100	6300	5200	2000
11				674	645	620	599	10	1100	4300	3200	6400	5300	2100
12			6	630	602	577	557	11	1200	4400	3300	100	5400	2200
13				590	563	540	520	12	1300	4500	3400	200	5500	2300
14				555	529	506	487	13	1400	4600	3500	300	5600	2400
15				523	498	476	458	14	1500	4700	3600	400	5700	2500
16			7	495	470	449	432	15	1600	4800	3700	500	5800	2600
17				469	445	425	409	16	1700	4900	3800	600	5900	2700
18				445	423	404	388	17	1800	5000	3900	700	6000	2800
19				424	402	384	368	18	1900	5100	4000	800	6100	2900
20				405	384	366	351	19	2000	5200	4100	900	6200	3000
21			8	387	366	349	335	20					6300	3100
22				370	351	334	321	21					6400	3200
23				355	336	320	307	22						
24				341	323	308	295	23						
25				328	311	296	283	24						
26			9	316	299	285	273	25						
27				305	288	275	263	26						
28				295	278	265	254	27						
29				285	269	256	245	28						
30				276	260	248	237	29						
31				267	252	240	230	30						
32				259	245	233	223	31						
33			0	251	237	226	216	32						
34				244	230	219	210	33						
35				237	224	213	204	34						
36				231	218	207	198	35						
37				225	212	202	193	36						
38				219	207	196	188	37						
39				213	201	191	183	38						
40				208	196	187	179	39						
41				203	192	182	174	40						
42				198	187	178	170	41						
43			1	194	183	174	166	42						
44				189	179	170	163	43						
45				185	175	166	159	44						
46				181	171	162	155	45						
47				177	167	159	152	46						
48				174	164	156	149	47						
49				170	161	153	146	48						
50				167	157	150	143	49						
				164	154	147	140	50						

Surface data

Temperature: DB___WB___DEP___
Pressure_____in.
Relative humidity_____%
Surface density_____%
Wind speed_____mph
Wind azimuth_____m
Upper clouds_____
Middle clouds_____
Lower clouds_____
Visibility_____
Tide_____ft.
Station elevation_____ft.

Meteorological message

M ... M ... Data sent to_____
2 ... ... _____
0 ... ... By_____
1 ... ... Time_____
2 ... ... Observer_____
3 ... ... Reader_____
4 ... ... Balloon lost because of_____
5 ... ... _____
6 ... ... Theodolite at reference point read
7 ... ... _____
8 ... ... _____
9 ... ... _____
0 ... ... _____
1 ... ... _____

FIGURE 11.—Form 1.

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ETEOROLOGICAL DATA SHEET, SIMPLIFIED METHOD, FOR ANTIAIRCRAFT ONLY

Ascension				Ballistic wind speed					Ballistic wind direction					
				Enter with elevation					Enter with azimuth angle					
in-te	2 Elevation angle (degrees)	3 Azimuth angle (degrees) from North	4 Zone	5 Zone 1	6 Zones 2 and 3	7 Zones 4 and 5	8 Over 5 zones	9 Speed	10 Azimuth	11 Direction	12 Azimuth	13 Direction	14 Azimuth	15 Direction
				90.0	90.0	90.0	90.0		2.8		120.9		239.1	
1			1	86.5	86.3	86.1	85.9	0	8.4	33	126.6	54	244.7	11
2			2	79.6	79.0	78.4	77.9	1	14.1	34	132.2	55	250.3	12
3				73.0	72.0	71.1	70.3	2	19.7	35	137.8	56	255.9	13
4			3	66.8	65.6	64.4	63.4	3	25.3	36	143.4	57	261.6	14
5				61.2	59.7	58.4	57.3	4	30.9	37	149.1	58	267.2	15
6			4	56.1	54.5	53.1	51.8	5	36.6	38	154.7	59	272.8	16
7				31.5	49.9	48.4	47.1	6	42.2	39	160.3	60	278.4	17
8			5	47.5	45.8	44.3	43.0	7	47.8	40	165.9	61	284.1	18
9				43.9	42.2	40.7	39.5	8	53.4	41	171.6	62	289.7	19
10				40.7	39.1	37.6	36.4	9	59.1	42	177.2	63	295.3	20
11				37.9	36.3	34.9	33.7	10	64.7	43	182.8	64	300.9	21
12			6	35.4	33.8	32.5	31.3	11	70.3	44	188.4	1	306.6	22
13				33.2	31.7	30.4	29.2	12	75.9	45	194.1	2	312.2	23
14				31.2	29.7	28.5	27.4	13	81.6	46	199.7	3	317.8	24
15				29.4	28.0	26.8	25.8	14	87.2	47	205.3	4	323.4	25
16			7	37.8	26.5	25.3	24.3	15	92.8	48	210.9	5	329.1	26
17				26.4	25.0	23.9	23.0	16	98.4	49	216.6	6	334.7	27
18				25.1	23.8	22.7	21.8	17	104.1	50	222.2	7	340.3	28
19				23.9	22.6	21.6	20.7	18	109.7	51	227.8	8	345.9	29
20				22.8	21.6	20.6	19.7	19	115.3	52	233.4	9	351.6	30
21			8	21.8	20.6	19.6	18.9	20	120.9	53	239.1	10	357.2	31
22				20.8	19.7	18.8	18.0	21					2.8	32
23				20.0	18.9	18.0	17.3	22						
24				19.2	18.2	17.3	16.6	23						
25				18.5	17.5	16.6	15.9	24						
26			9	17.8	16.8	16.0	15.4	25						
27				17.2	16.2	15.4	14.8	26						
28				16.6	15.7	14.9	14.3	27						
29				16.0	15.1	14.4	13.8	28						
30				15.5	14.6	13.9	13.3	29						
31				15.0	14.2	13.5	12.9	30						
32				14.6	13.8	13.1	12.5	31						
33			0	14.1	13.3	12.7	12.2	32						
34				13.7	13.0	12.3	11.8	33						
35				13.3	12.6	12.0	11.5	34						
36				13.0	12.3	11.7	11.2	35						
37				12.6	11.9	11.3	10.9	36						
38				12.3	11.6	11.0	10.6	37						
39				12.0	11.3	10.8	10.3	38						
40				11.7	11.0	10.5	10.0	39						
41				11.4	10.8	10.2	9.8	40						
42				11.2	10.5	10.0	9.6	41						
43			1	10.9	10.3	9.8	9.4	42						
44				10.6	10.1	9.6	9.1	43						
45				10.4	9.8	9.3	8.9	44						
46				10.2	9.6	9.1	8.7	45						
47				10.0	9.4	8.9	8.6	46						
48				9.8	9.2	8.8	8.4	47						
49				9.6	9.0	8.6	8.2	48						
50				9.4	8.9	8.4	8.0	49						
				9.2	8.7	8.2	7.9	50						

Surface data

Temperature; DB____WB____DEP____
Pressure_____in.
Relative humidity_____%
Surface density_____%
Wind speed_____m. p. h.
Wind azimuth_____m
Upper clouds_____
Middle clouds_____
Lower clouds_____
Visibility_____
Tide_____ft.
Station elevation_____ft.

Meteorological message

M			M				Data sent to_____
2							
0							By_____
1							Time_____
2							Observer_____
3							
4							Reader_____
5							Balloon lost because
6							of_____
7							
8							Theodolite at refer-
9							ence point read__
0							
1							

FIGURE 12.—Form 2.

[A. G. 300.7 (21 Aug 43).] (C 4, 17 Sep 43.)

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APPENDIX I

METEOROLOGICAL TABLES

Table X–1n (added by C 1, 7 Sept. 1942), change title to read as follows: FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRE; VALID DURING THE NIGHT IN REGION 1 (EASTERN U. S. A., BRITISH ISLES, COAST OF NORTH AFRICA, AND EUROPE, EXCEPTING ALPINE REGION, SCANDINAVIAN PENINSULA, AND RUSSIA NORTH OF LATITUDE 55° N.).

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Table X–3n (added by C 1, 7 Sept. 1942), change title to read as follows: FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRE; VALID DURING THE NIGHT IN REGION 3 (WESTERN U. S. A. AND ALPINE REGION OF SOUTHERN EUROPE).

Table X–3a (added by C 1, 7 Sept. 1942), change title to read as follows: FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRE; VALID DURING THE AFTERNOON IN REGION 3 (WESTERN U. S. A. AND ALPINE REGION OF SOUTHERN EUROPE).

Table X–5 (added by C 1, 7 Sept. 1942), change title to read as follows: FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRE; VALID IN REGION 5 (ALASKA, ICELAND, SCANDINAVIAN PENINSULA, AND RUSSIA NORTH OF LATITUDE 55° N.).

Table X–6n (added by C 1, 7 Sept. 1942), change title to read as follows: FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRES; VALID DURING THE NIGHT IN REGION 6 (WEST INDIES, CANAL ZONE, HAWAII, AND SOUTHWEST PACIFIC AREA).

Table X–6a (added by C 1, 7 Sept. 1942), change title to read as follows: FOR ANTIAIRCRAFT ARTILLERY AND OTHER HIGH-ANGLE FIRE; VALID DURING THE AFTERNOON IN REGION 6 (WEST INDIES, CANAL ZONE, HAWAII, AND SOUTHWEST PACIFIC AREA).

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EASTERN ASIA REGION: Since there are no aerological data available, it is recommended that the original tables X and XII be used in the Eastern Asia region.

[A. G. 300.7 (21 Aug 43).] (C 4, 17 Sep 43.)

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

J. A. ULIO,
Major General,
The Adjutant General.

U. S. GOVERNMENT PRINTING OFFICE: 1943

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TECHNICAL MANUAL
No. 4-240

WAR DEPARTMENT,
WASHINGTON, December 20, 1941.

METEOROLOGY FOR COAST ARTILLERY

Prepared under direction of the
Chief of Coast Artillery

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*This manual supersedes TR 1236–1, June 20, 1934.

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SECTION I

GENERAL

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Purpose and scope 1
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1. Purpose and scope.—*a.* The purpose of this manual is to provide instructions and technical meteorological knowledge needed by personnel serving at coast artillery meteorological stations. These stations are operated for the purpose of supplying meteorological data to coast artillery batteries.

b. The scope of this manual includes general information pertaining to the phenomena considered, a description of the meteorological equipment and supplies, and instructions for making the necessary meteorological observations for reducing the data to the proper form and for preparing the meteorological message for the firing units.

2. Meteorological data required by coast artillery firing units.—*a.* The artilleryman computing firing data should know the value of three meteorological conditions at the time of firing; namely, air temperature, air density, and wind. Variations in the value of any of these conditions cause variations in the distance or direction that a projectile will travel after being fired from a gun. Other atmospheric conditions may influence the travel of the projectile, but usually not appreciably; therefore, only the three conditions named above are considered. The behavior of the projectile is influenced by the atmosphere not only near the gun but along the entire path followed by the projectile from the gun to the target. Projectiles sometimes reach a height of several miles and, since atmospheric conditions vary

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with altitude, it is necessary to consider the air temperature, air density, and wind at various altitudes along the trajectory.

b. (1) Basic firing tables have been computed with certain atmospheric conditions assumed as standard. These standard atmospheric conditions are as follows:

(*a*) The air temperature at the gun is 59° F. and decreases in a particular manner as the altitude increases.

(*b*) The air density at the gun is 525.9 grains per cubic foot and decreases in a particular manner as the altitude increases.

(*c*) There is no wind.

(2) The variations in standard air temperature and density with altitude are shown in table V (for tables I to XIII, incl., see app. I). The actual atmospheric conditions are seldom those that have been assumed as standard. Firing tables contain data, known as differential effects, from which the artilleryman may determine the corrections that should be applied to firing data to correct for variations from standard atmospheric conditions. The differential effects listed for nonstandard air temperatures are for temperatures at the gun and include the effect of the variations in temperature with altitude throughout the trajectory. Consequently, it is necessary for the meteorological station to furnish the firing unit with the air temperature at the surface only. The differential effects listed for air density and wind are for uniform nonstandard conditions. For example, the wind effects are for a wind of uniform speed and direction throughout the entire trajectory. To enable the artilleryman to determine expeditiously the necessary corrections to be applied for nonstandard density and wind, the actual conditions at the various altitudes are reduced to fictitious uniform conditions which would have an effect on the travel of the projectile equal to the combined effects of the actual conditions of density and wind encountered throughout the entire trajectory. These fictitious conditions are called ballistic density and ballistic wind.

c. The present practice of making the necessary meteorological observations is to determine the air temperature and the air density at the surface only. The values of these two elements are assumed to decrease in a particular manner as the altitude increases. The air temperature is measured directly with a thermometer. The surface air density is determined from measurements of the temperature, the pressure, and the relative humidity of the atmosphere, and the ballistic densities for various altitudes are determined from tables of ballistic densities. The speed and direction of the wind at various altitudes are determined from the horizontal component of the travel

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of a hydrogen-filled free balloon, known as a pilot balloon, which is tracked in azimuth and elevation by means of a theodolite. In order that wind speeds may be determined from the travel of the balloon, the position of the balloon must be determined at definite time intervals. This requires periodic observations of the azimuth and the elevation of the balloon. The standard procedure is to make these observations at 1-minute intervals. The use of only one theodolite station requires the assumption that the balloon ascends at a predetermined rate and that the altitude of the balloon is a function of the time that it has been in the air. To simplify the determination of the ballistic winds, the atmosphere is divided into altitude layers or zones which are referred to in this manual as altitude zones. The resultant wind is determined for each of these zones, and the ballistic winds for various altitudes are determined by weighting the resultant winds and combining them into an assumed wind of uniform direction and speed. Tables of weighted wind speeds are provided for this purpose.

d. It has been stated in *c* above that ballistic densities and ballistic winds are determined for various altitudes. It would be impracticable to determine these ballistic data for all altitudes that may be desired by the artillery. Consequently, ballistic densities and ballistic winds are determined only for certain fixed altitudes above the meteorological station, and the artilleryman uses the data for the altitude which is most suitable for his problem. These fixed altitudes correspond to the upper limits of the altitude zones, and are referred to in this manual as standard altitudes. Further discussion of altitude zones and standard altitudes appears in subsequent sections. Data pertaining to the surface wind and the surface air density also are furnished to the artillery.

e. It has been recognized that under certain atmospheric conditions, the assumption that the balloon rises at a certain rate may be in error. Recent studies have indicated also that the assumptions of variations in air temperature and air density with altitude may not be always correct. Developments are now in progress for finding means suitable for military use of determining more accurately the travel of a free balloon, and of actually measuring the air temperature and density at various altitudes. However, with the present coast artillery meteorological equipment, the assumptions discussed above must be made.

f. (1) To summarize briefly the contents of this paragraph, the coast artillery meteorological station furnishes to the firing units the following meteorological data:

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(*a*) Surface air temperature, surface wind, and surface air density.

(*b*) Ballistic winds for various standard altitudes determined from pilot balloon observations.

(*c*) Ballistic densities for various standard altitudes determined from surface observations.

(2) These data are furnished to the firing units in a coded message known as the meteorological message.

3. Standard methods and equipment.—*a.* To obtain satisfactory meteorological data, the measuring instruments must be exposed or used in accordance with standard practice, and the reduction of the data must be accomplished in accordance with standard procedure. When, for instance, the air temperature is to be measured, the measurements should be made in such a manner that the results indicate the temperature of a considerable amount of free air at the time and place the measurements are made. This procedure involves more attention to details than is generally realized. A thermometer attached to the side of a building is likely to indicate the temperature of the side of the building and not the temperature of the surrounding air. Likewise, approved methods must be followed in making the measurements and reducing the data to determine the ballistic density and wind. Failure to follow recognized rules may cause the resulting data to be entirely worthless.

b. Since atmospheric conditions are subject to continual change, the data contained in the meteorological message should be the result of measurements made as near to the actual time of firing as practicable. Consequently, the meteorological observations and the preparation and transmission of the meteorological message should be accomplished as rapidly as is consistent with good results. This calls for proper planning and coordination on the part of all personnel serving at the meteorological station.

c. Table XIII lists the standard equipment and supplies for a coast artillery meteorological station. There is not a great amount of equipment, and care and maintenance are not difficult. However, it is important that care and maintenance be emphasized with a view to preventing personnel serving at the station from becoming careless. The theodolite and all instruments used for making meteorological measurements are delicate and must be handled with care and kept in good condition and adjustment. Some of the articles of equipment are small in size and are easily lost. A definite place should be provided for keeping each article when not in use. Expendable items demand careful supervision to insure that an adequate supply is

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always on hand and that the items are serviceable. The lack of one article may prevent the meteorological station from functioning.

4. Location of meteorological station and theodolite station.—*a.* Harbor defense meteorological stations are permanent installations. A building is usually provided for this purpose. The location of the theodolite station is also permanent. The harbor defense artillery engineer is responsible for determining the height of the meteorological station and for providing the necessary orientation data for the theodolite station. A permanent record should be made of these data. A mobile regiment must establish new locations for the meteorological station and the theodolite station for each major change in position of the firing units. These stations should be located where they will best serve the firing units of the regiment. A location near the regimental command post is usually suitable. It is contemplated that mobile regiments will be provided with meteorological trailers for the transportation and operation of meteorological equipment. Until such provision is made, mobile regiments must provide shelters or make use of available buildings for meteorological stations. Reconnaissance officers within the mobile regiments are responsible for determining the height of the meteorological station and for providing the necessary orientation data for the theodolite station. These data should be recorded carefully.

b. The meteorological station should be located where the data collected will be representative of the general atmospheric conditions of the firing areas. Space should be available for the exposure of the instruments where the atmospheric conditions will not be influenced by nearby structures. All altitudes named in the meteorological message are altitudes above the meteorological station. Small differences in heights of site between the artillery and the meteorological station will not introduce appreciable errors, since each firing unit applies corrections for such differences. However, the difference should not exceed 500 feet.

c. The location of the theodolite station should provide an unobstructed view of the entire sky down to 6° above the horizon, and should be as near as practicable to the meteorological station. This location should be suitably marked so that the theodolite can be placed readily in the same position for each ascension of a balloon. For temporary stations, a level spot on the ground may be selected and a stake driven into the ground to mark the plumb bob center of the theodolite. The provision of three holes 2 or 3 inches deep for the tripod legs will facilitate the setting up of the theodolite and will also aid in protecting the instrument from being damaged or jarred out

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of adjustment. At permanent stations there should be provided a substantial platform with fixed holes for the tripod legs and a marker for the plumb bob center of the theodolite. This platform may be located on the ground or on the roof of a building, provided the building is built solidly and does not vibrate in the wind.

d. Although it has been stated in *a* above that harbor defense artillery engineers and reconnaissance officers are responsible for providing the necessary orientation data for theodolite stations, all personnel serving at coast artillery meteorological stations should have a knowledge of the basic principles of orientation. Several methods of establishing datum points for orienting observing instruments are described in TM 5–235. The theodolite itself may be used in lieu of the transit for such purposes. In the event that orientation data are not available at a theodolite station, the personnel thereat should know at least how to establish a reference point by means of a compass. *All azimuths at coast artillery meteorological stations are expressed in terms of angles measured clockwise from grid north.*

5. Duties of personnel.—Four enlisted men are considered the normal operating personnel for a coast artillery meteorological station. Each man should be trained to perform all the routine duties, and it should be the practice occasionally to rotate the men through all the duties. Routine duties are normally assigned as indicated below:

a. Observer.—Sets up and orients the theodolite, observes the ascension of the balloon through the theodolite, and replaces the theodolite in its box at the completion of his duties.

b. Reader.—Connects the timing and telephone set, inflates the balloon, releases the balloon at the proper time, reads the azimuth and elevation of the balloon at 1-minute intervals during the ascension, and transmits these data to the plotter.

c. Plotter.—In charge of the meteorological station and is responsible for its functioning as a whole. He plots the projection of the travel of the balloon on the plotting board ML–122 or ML–55, determines graphically the wind for each altitude zone, makes the surface observations, reduces the surface data to proper form, determines the ballistic densities for each standard altitude, consolidates all data on W. D., Sig. C. Form No. 206 (Meteorological Data Sheet for Artillery (fig. 9)), and prepares and dispatches the meteorological message.

d. Assistant plotter.—Determines on the plotting board ML–120 or ML–57 the ballistic wind for each of the standard altitudes and assists in other duties whenever practicable.

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6. Steps in preparing meteorological message.—The theodolite station having been located, the necessary data for orienting the theodolite being on hand, and a means for transmitting periodic data from the reader to the plotter having been established, the preparation of the meteorological message may be divided into the operations listed below:

a. Determine the wind for each altitude zone.

(1) Set up and orient the theodolite.

(2) Inflate and weigh the balloon.

(3) Track the free balloon in azimuth and elevation.

(4) Plot the horizontal projection of the travel of the balloon on the plotting board ML–122 or ML–55.

(5) Determine the wind for each altitude zone from the above plot.

b. Determine the ballistic winds for each standard altitude.

(1) Obtain from the proper tables the weighted wind speeds for each altitude zone.

(2) Plot the weighted winds on the plotting board ML–120 or ML–57.

(3) Determine the ballistic wind for each standard altitude from the above plot.

c. Make the surface observations. Determine—

(1) Atmospheric pressure.

(2) Relative humidity.

(3) Air temperature.

(4) Surface air density.

(5) Surface wind.

d. Determine the ballistic densities for each standard altitude.

e. Encode the meteorological message and dispatch the message to the proper distributing center.

SECTION II

TELEPHONE AND TIME INTERVAL SYSTEMS

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Standard equipment 7
Methods employed without standard equipment 8

7. Standard equipment.—*a. General.*—(1) The timing and telephone set ML–110 is the standard equipment used in theodolite observations of pilot balloons to provide a means of—

(*a*) Telephonic communication between the reader and the plotter.

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(*b*) Superimposing automatic timing signals on the communication line to aid the observer and the reader in making periodic observations of the position of the balloon.

(2) In timing the ascension of a balloon, all times are measured from the time of release of the balloon, which is time zero. The complete timing and telephone set ML–110 consists of the component parts listed below:

1 time interval unit ML–138.
2 head and chest sets HS–25.
2 plugs PL–57 (includes one spare).
1 jack JK–39.
2 batteries BA–30.

(3) The set is equipped with sound-powered telephones which require no battery power for their operation. However, battery power is required to operate the tone-generating unit which superimposes time signals on the communication line. The power required is very low, and long life should be obtained from a set of batteries. The normal operating range of the equipment is much greater than ordinarily will be required at coast artillery meteorological stations. A detailed description of the set and detailed instructions for its care and operation appear in the instruction book which accompanies each set. Only the general features of the equipment will be discussed in this manual.

b. Time interval unit ML–138.—(1) This unit consists of a clock-operated mechanism, a tone source, a battery box containing two batteries, and necessary controls, all mounted in a metal case. On the panel of the unit are mounted a screw driver and a clock key. A removable wall bracket for mounting the unit is attached to the back of the case.

(2) There are four openings with hinged covers in the front of the case. The two lower openings are for inserting the clock key to wind the clock mechanism. The two upper openings provide access to two identical jacks. The plug PL–57 and the plug on the end of the cord of the plotter's head and chest set are inserted in the jacks when the unit is in use. The jacks are wired in parallel; hence, either plug may be placed in either jack.

(3) The control panel for the time interval unit is mounted at the top of the unit just under the cover. The two binding posts marked EXT. BAT. are for an external battery source of power if this is necessary. Normally power is supplied by two batteries BA–30 located within the unit. The double-throw toggle switch, marked EXT. BAT. and INT. BAT., is used to connect either of

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these two power sources. The single-throw toggle switch on the panel is for disconnecting the source of power when the unit is not in use. The control marked TONE VOLUME is for adjusting the intensity of the time interval signal. The two binding posts marked LINE are connected in parallel with the two jacks mounted at the front of the unit. These binding posts are for emergency line connections when the plug PL–57 is not available or when it is desired to transmit the time interval signal to more than two telephone stations.

(4) The clock mechanism automatically closes an electrical circuit once each minute to produce a tone signal of about 5 seconds' duration.

c. Head and chest set HS–25.—This equipment consists of a lightweight, chest-type transmitter and a single earpiece receiver connected to a 10-foot cord which terminates in a plug. The chest plate of the transmitter unit is provided with two adjustable web straps, one attached to the top corners of the chest plate and one attached to the bottom corners. The upper strap is placed around the telephone operator's neck, and the lower strap is placed around his body. If the strap lengths are properly adjusted, the chest plate will be held close to the body and will not interfere with other operations.

d. Installation.—(1) In fixed meteorological stations or in mobile stations in vehicles, the time interval unit ML–138 should be permanently installed near the plotting board ML–122 or ML–55. The wall-mounting bracket is provided for this purpose. The unit should be mounted so that it is easily accessible for winding the clock, inserting the phone plug, and changing the batteries. The cord to the plotter's phone and the line to the theodolite station should not interfere with the plotting operations.

(2) The communication line between the theodolite station and the meteorological station may consist of field wire W–110 or any two-conductor cable of reasonably satisfactory electrical qualities. At harbor defense meteorological stations the communication lines should be permanently installed. At the meteorological station, the line is connected to the binding posts on the plug PL–57, which is inserted into one of the jacks of the time interval unit. The plug of the plotter's head and chest set is inserted into the other jack. At the theodolite station the line is connected to the jack JK–39. The plug of the reader's head and chest set is inserted into this jack. This provides a complete communication circuit with a time interval system superimposed on the communication line.

e. Operation.—The operation of the timing and telephone set ML–110 is very simple. After the proper connections have been made

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and the meteorological balloon is ready to be released, completely wind both springs of the clock. Throw the single-throw toggle switch to the ON position to provide battery power to the time interval unit. A tone signal of about 5 seconds' duration should be heard at 1-minute intervals in each telephone receiver. Adjust the TONE VOLUME control so that a tone signal of desired intensity is obtained. The timing and telephone set will function automatically while in use. The balloon is released at the end of one of the tone signals. No separate signal is provided as a warning before the reading signal. However, since the duration of each tone signal is about 5 seconds, the beginning may be used as a warning signal and the end as a reading signal. The reader at the theodolite is provided with one of the head and chest sets. At the beginning of each tone signal he warns the observer that a reading is about to be made by announcing "Ready." At the end of each tone signal, the reader announces "Read." After a little practice it will be found that this method of timing the readings will be very satisfactory. At the completion of the tracking of the balloon, the battery power should be turned off in order to conserve the batteries. The timing and telephone set should be used wherever it is available, even though the distance between the reader and the plotter is such that telephone communication would not be necessary.

8. Methods employed without standard equipment.—*a.* If the timing and telephone set ML–110 is not available, other means must be provided for timing the observations of the balloon and transmitting the data from the reader to the plotter. A stop watch or a wrist watch with a second hand may be used by the reader to time the ascension of the balloon. After the balloon is released, 5 seconds before each minute the reader warns "Ready." At each minute he announces "Read." Telephone communication between the reader and the plotter may be provided by utilizing equipment available within the harbor defense or regiment. The following telephones have been issued for use at meteorological stations and may be used as substitute equipment:

(1) Head and chest set HS–17–A.
(2) Head and chest set HS–19.
(3) Head set EE–70.

b. Sufficient information for connecting the above types of equipment is available in pertinent manuals.

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SECTION III

DETERMINING ZONE WINDS

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9. Description of theodolite ML–47.—*a.* The theodolite is a special type of telescope mounted on a tripod and provided with a vertical and a horizontal circle graduated in degrees, by means of which angles of elevation and azimuths may be measured. It is provided also with tangent screws by means of which an observer may follow the flight of a pilot balloon. The elevation and azimuth of the balloon may be read at any instant.

b. The term "angle of elevation" as used in *a* above is the vertical angle expressed in degrees and tenths between the line of sight to the balloon and the horizontal plane through the theodolite.

c. The term "azimuth" as used in *a* above is the horizontal angle expressed in degrees and tenths between the vertical plane of the line of sight to the balloon and a north-south line, and is measured clockwise from grid north.

d. The theodolite ML–47 is illustrated in figure 1. It consists of the following principal parts and accessories:

(1) *Principal parts.*—(*a*) An elbow telescope.

(*b*) Two circular limbs graduated in degrees and equipped with verniers. The vertical circle is used for reading angles of elevation, and the horizontal circle for reading azimuths. The telescope can be moved slowly and progressively by turning the milled heads of the two tangent screws which are attached to the vertical and horizontal circles. These tangent screws can be disengaged and reengaged at will, and are held in gear by the action of springs.

(*c*) A leveling head with three leveling screws which support the entire instrument. These screws are adjusted by reference to the spirit levels fixed to the theodolite.

(2) *Accessories.*—(*a*) Brass covers to protect the objective, the eyepiece, and the prism when the theodolite is not in use; a sunshade; lighting equipment for night observations; a wooden box serving as

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a case for the instrument, which contains a screw driver, a plumb bob, and an adjusting pin. This box also contains a shelf upon which the telescope should be placed when packing the theodolite for ship-

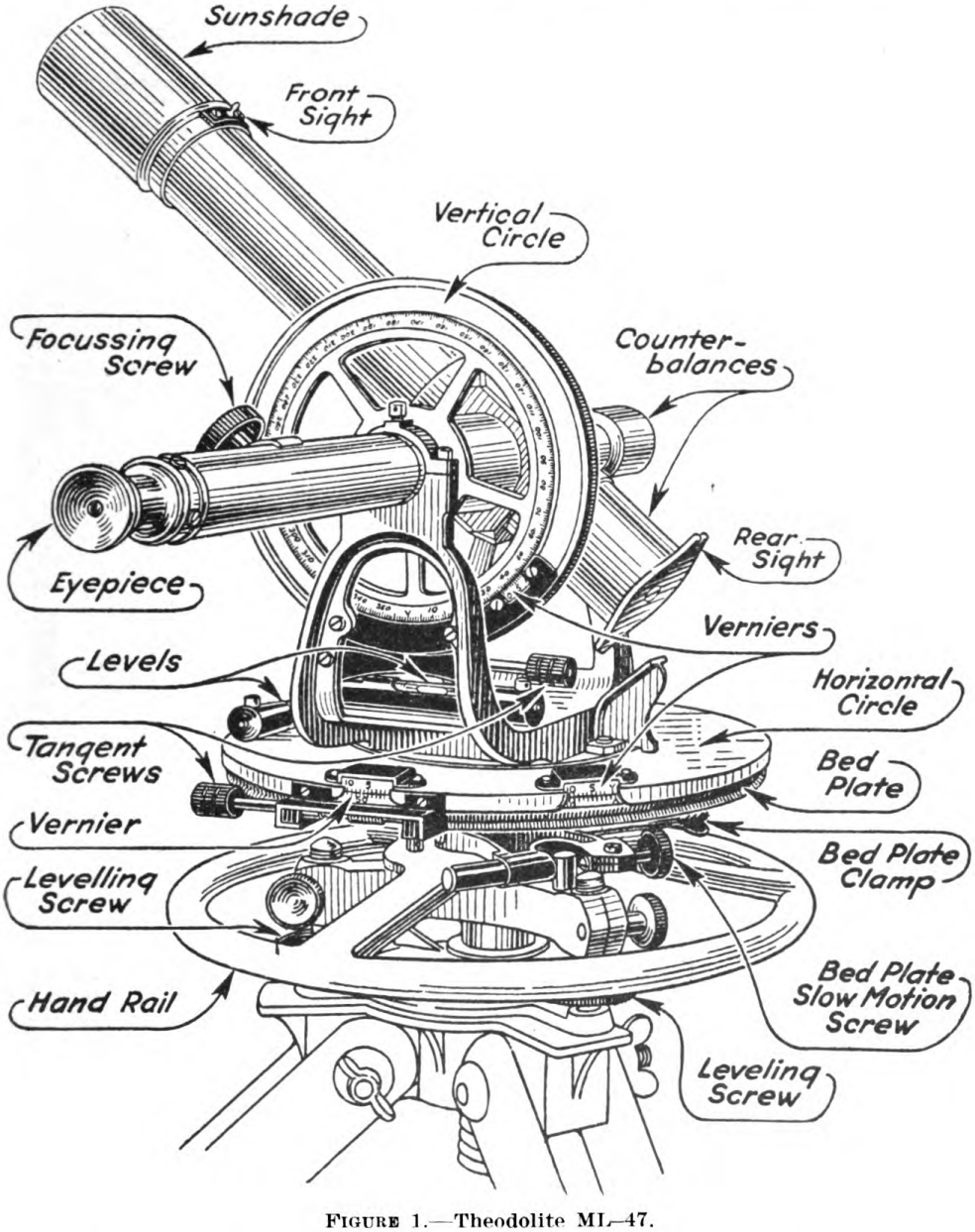


FIGURE 1.—Theodolite ML–47.

ment (see fig. 2). It is not necessary to remove the telescope from the theodolite when the instrument is stored for short periods at the meteorological station. By sliding the upper shelf from the box, the theodolite may be stored in the box without removing the telescope.

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(*b*) A wooden tripod with a metal head (see fig. 3). This tripod head is fitted with a movable metal platform which facilitates placing the theodolite over a given point.

e. The smallest graduation on the circular limbs is 1°. The verniers are used for obtaining readings to the nearest tenth of a degree. The

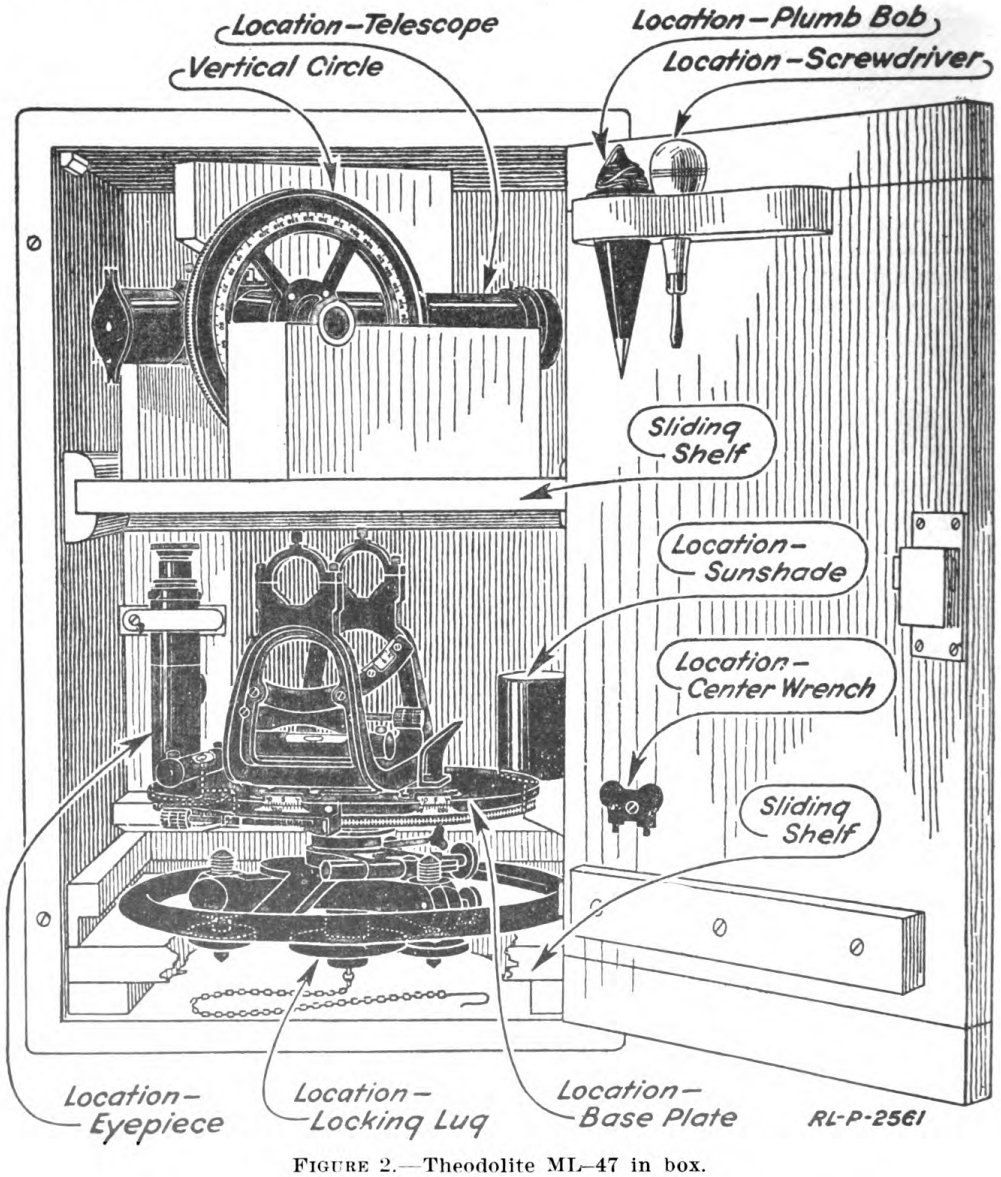


FIGURE 2.—Theodolite ML–47 in box.

verniers on theodolite ML–47 are direct verniers. It will be noted from figure 1 that two verniers are provided for the horizontal circle. The rear vernier is more conveniently located for the reader. Care must be exercised to read azimuths by means of the same vernier that is used in orienting the theodolite in direction. The number of whole

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degrees is read directly from the circular limb. The number of tenths of a degree is obtained from the vernier by following along the vernier until a graduation is found to coincide or most nearly coincide with

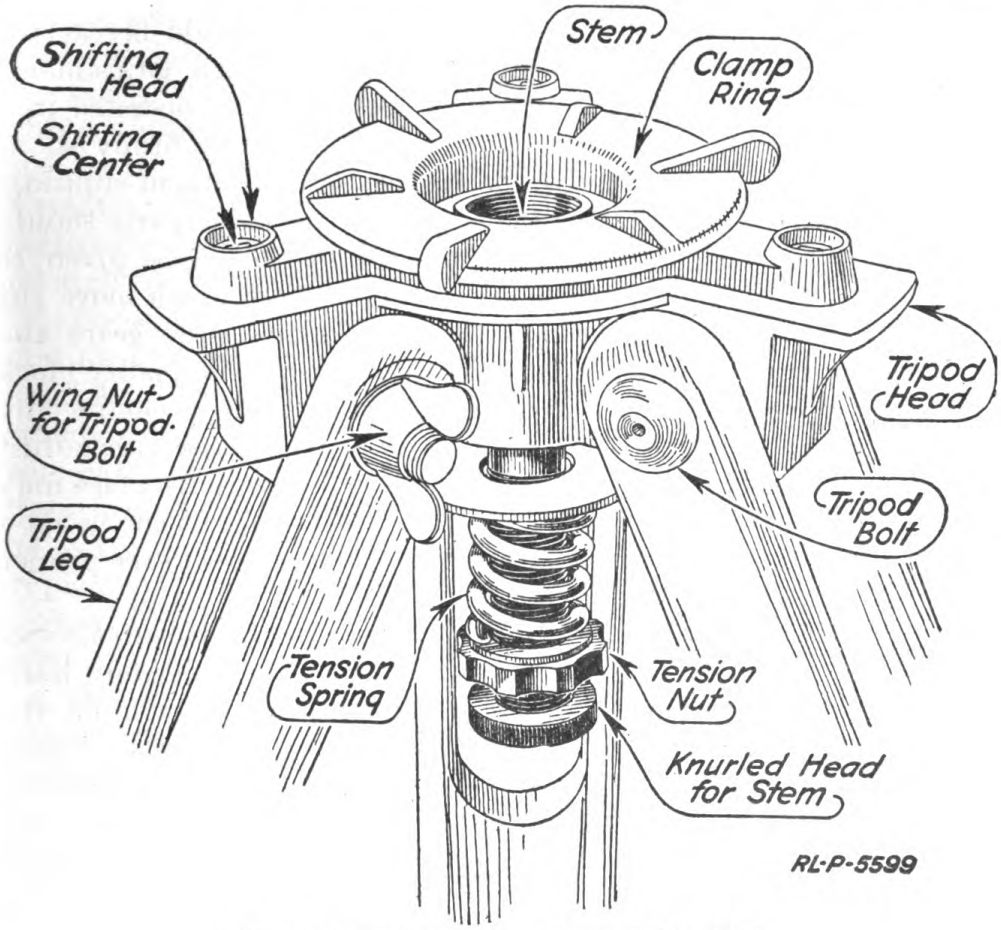


FIGURE 3.—Theodolite tripod and shifting head.

a graduation on the circular limb. Figure 4 illustrates an azimuth reading of 28.7° on the horizontal limb.

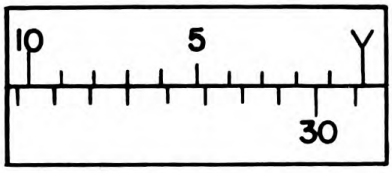


FIGURE 4.—Theodolite vernier (horizontal limb).

10. Care of theodolite.—Special attention should be given to the care and use of the theodolite. This instrument is delicate and expensive, and should be handled only by persons who have had

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thorough instruction in its care and use. When the theodolite is being carried, it should be securely attached to the tripod. The bedplate clamp should be loose so that the head of the theodolite is free to revolve in case it strikes another object. Outdoors the instrument should be carried over the shoulder. Indoors it should be carried under the arm, with the telescope to the front. All adjustments should be made carefully. Adjusting screws should be operated uniformly without strain. Motion clamps should be set firmly so as to secure a positive motion with the tangent screws without slipping. Before the theodolite is replaced in its box, the metal parts should be wiped with a soft cloth. Special attention should be given to the removal of dust and grit from the worm gears which move the horizontal and vertical limbs. From time to time these gears and the tangent screws should be oiled lightly with a good quality clock oil. No attempt should be made to disassemble the theodolite any further than is necessary to store it in its box. In case either dust or moisture is to be removed from the lenses, the exterior surface may be wiped with a clean piece of chamois. If the instrument needs a thorough cleaning or repairing, it should be turned over to the proper Signal Corps service agency.

11. Setting up and orienting theodolite.—*a. Preparation.*—Set the tripod firmly on the ground with the plate approximately horizontal. Remove the theodolite from the box and place it on the plate of the tripod, with the leveling screws in their sockets. Screw the vertical pin into the tapped hole in the base of the instrument by means of the corrugated head below the plate of the tripod. By means of the knurled nut on the vertical pin, tighten the brass spring. Remove the protecting cap from the telescope barrel, screw on the eyepiece tube, and place the sunshade on the objective. Turn the telescope so that it points vertically upward, and engage the vertical motion tangent screw. Loosen the bedplate clamp. Bring the legs of the tripod together, carefully supporting the theodolite proper. The instrument is now ready to be carried to the theodolite station.

b. Setting up.—Carry the theodolite and tripod to the theodolite station and set up the instrument in the place that has been provided for it. Attach the plumb bob. Adjust the tripod legs to place the theodolite at the proper height, and to place the plumb bob almost directly over the station marker. Final centering of the plumb bob is obtained by means of the shifting head on the plate of the tripod. This is accomplished by loosening the tension nut and the clamp ring, and sliding the shifting head to the desired position. When the plumb bob has been centered, tighten the tension nut and clamp ring.

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c. Leveling.—The theodolite ML-47 is provided with three leveling screws and two levels. Rotate the head of the instrument so that one of the levels is parrallel to a line passing through two of the leveling screws. Center the bubble in this level by turning the two leveling screws simultaneously in opposite directions. Center the bubble in the second level by turning the third leveling screw in one direction or the other. If necessary, repeat this operation until both bubbles are centered. Check level by rotating the theodolite through 360° in 120°-steps. The bubbles should remain centered regardless of rotation of the theodolite. When the leveling has been completed, tighten the brass spring to hold the theodolite firmly on the tripod, and tighten the horizontal screws on the leveling posts.

d. Focusing.—Bring the cross hairs of the telescope in focus by rotating the eyepiece until the cross hairs are seen with maximum sharpness. Focus the telescope by means of the focusing screw until the image of an object at least 100 feet away is clearly defined and free from parallax. The term "parallax" as used here denotes an apparent slight motion of the cross hairs across the field of the telescope when the eye is moved from side to side or up and down in rear of the eyepiece. When no parallax is present, the cross hairs do not appear to move. Focusing adjustments should be made in the order indicated above.

e. Orienting.—After the theodolite has been leveled and focused, it should be oriented on the datum point established for that purpose. Disengage the tangent screw and rotate the theodolite until the horizontal circle indicates the approximate azimuth from the theodolite station to the datum point. Engage the tangent screw and set the horizontal circle to read the exact azimuth to the datum point. Loosen the bedplate clamp so as to allow the whole instrument to rotate freely about its vertical axis, and point the telescope so that it is directed approximately at the datum point. Tighten the bedplate clamp and complete the azimuth adjustment by means of the bedplate slow motion screw, placing the vertical cross hair exactly on the datum point. Since the rotation of the bedplate does not change the reading of the horizontal circle, the azimuth reading is the azimuth to the datum point, and the theodolite is oriented.

f. Adjustments for accuracy.—The above instructions for setting up and orienting the theodolite presuppose that the instrument itself is accurately adjusted. Periodic tests and adjustments for accuracy should be made. Appendix II describes the accuracy adjustments that may be made by the personnel serving at coast artillery meteorological stations.

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12. Other types of theodolites.—*a.* The theodolite ML–47 discussed above is the type in use at almost all coast artillery meteorological stations. New theodolites now being procured for the Army are basically the same as the theodolite ML–47.

b. The White theodolite (fig. 5) is one of the latest type and is designated theodolite ML–47–C. This instrument has four leveling screws instead of three. To level the theodolite, rotate the instrument so that the levels are parallel to lines joining two diagonally opposite leveling screws. Center the bubble in one level by turning a pair

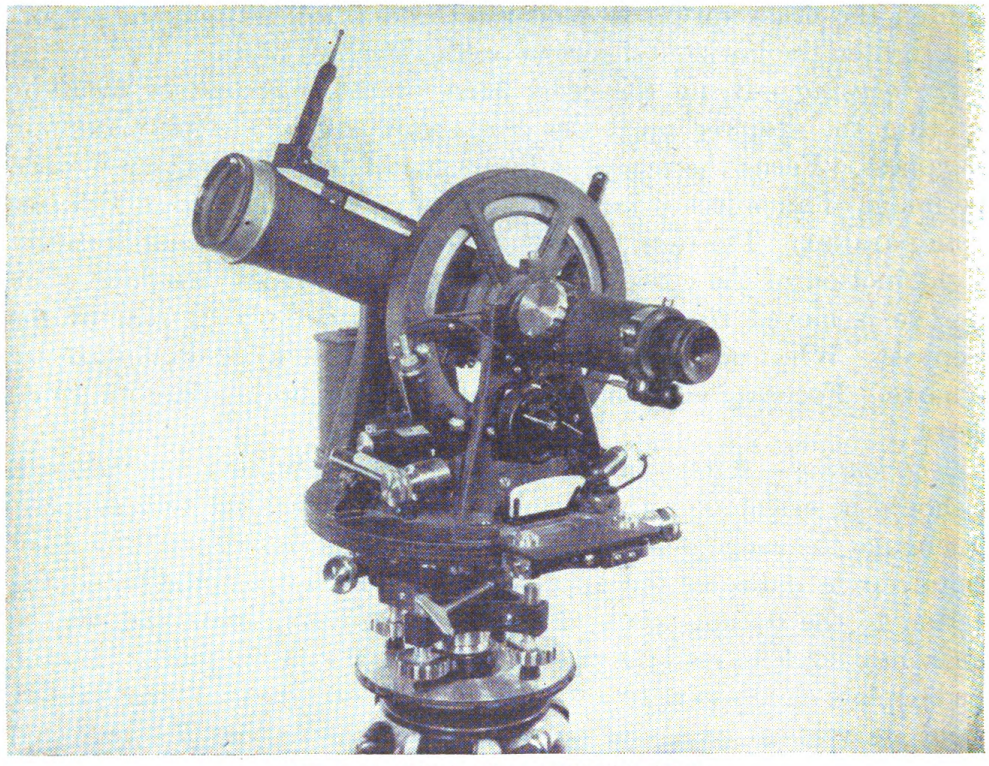


FIGURE 5.—White theodolite ML–47–C.

of opposing leveling screws in opposite directions. Center the bubble in the other level by means of the other set of leveling screws. If necessary, repeat this operation until both bubbles are centered. Check level by rotating the theodolite through 360° in 90° steps.

c. Theodolite ML–47–C is provided with a drum micrometer instead of a vernier for reading tenths of a degree. Whole degrees are read from the horizontal and vertical circles, and the tenths of a degree are read directly from the micrometers which are integral with the horizontal and vertical slow motion tangent screws.

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d. In general, the basic principles in paragraphs 9, 10, and 11 may be used as a guide for the operation and maintenance of the new types of theodolites.

13. Pilot balloon and hydrogen.—*a. General.*—Pilot balloons used at coast artillery meteorological stations are inflated with hydrogen. The hydrogen gas is furnished under high pressure in steel cylinders. The amount of hydrogen contained in one cylinder is equivalent to about 180 to 200 cubic feet at standard atmospheric conditions. This amount is sufficient to inflate 20 to 25 standard 30-gram pilot balloons. All 30-gram pilot balloons furnished to coast artillery meteorological stations are of the same size and quality. They are furnished in 5 colors. Balloon ML–50 is of neutral color and is most suitable for use on clear days. Balloon ML–51 is black and is most suitable for use on cloudy days. Balloon ML–64 is red and is most suitable for use on foggy and partly cloudy days. Balloons ML–155 (orange), and ML–156 (yellow) are for use on hazy days.

b. Care.—(1) Pilot balloons should be stored in a cool, dry place in a closed box, and should be covered with powdered talc and loosely packed. This method of storage will help prevent the balloons from deteriorating and sticking together. The powdered talc found on the balloons when originally received should not be removed. A balloon which is cold is likely to burst during inflation. The balloon should be made soft and pliable by uniform warming and gentle kneading before it is inflated. The balloon may be warmed by holding it near a stove or a radiator, or by placing it under the outer clothing for a few minutes.

(2) Hydrogen is highly inflammable, and when mixed with air is subject to explosion if ignited. Care must be exercised to minimize the fire hazards incident to the use of hydrogen. The hydrogen cylinders will be stored in a well-ventilated place. Under no circumstances will hydrogen cylinders, either full or empty, be stored in a closed place which could act as a trap for escaped hydrogen, nor will the pilot balloons be inflated or weighed in such a place. Overhead ventilation should be provided when balloons are inflated indoors. When balloons are inflated and weighed outdoors, they should be sheltered from the wind. Open flames will not be permitted near the hydrogen cylinders at any time.

c. Rate of ascent.—(1) A pilot balloon ascends at a fairly uniform rate because the volume of the balloon increases with a decrease in air pressure. The rate of ascent of a balloon depends upon its free lift which may be defined as the upward force in grams or ounces that a balloon exerts after it is filled with hydrogen. This free lift

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is equal to the weight which the inflated balloon will support in equilibrium in the atmosphere. The following formula may be used to determine the rate of ascent of a pilot balloon:

$$V = 158\left(\frac{l}{L^{2/3}}\right)^{5/8}$$

where V is the rate of ascent in yards per minute, l is the free lift of the balloon in ounces, and L is the total lift of the balloon in ounces. The total lift includes the weight of the balloon and gas.

(2) The cock ML–56 weighs 4.66 ounces, which is the free lift required to cause a balloon weighing 1.06 ounces to ascend at a calculated rate of 200 yards per minute. Specifications for the standard pilot balloon prescribe that the balloon will weigh not more than 1.2 ounces nor less than 0.9 ounces. Variations in weight between these limits will not affect materially the rate of ascent. It has been found by experience that near the ground balloons ascend faster than the calculated rate of ascent. This increase in rate has been found to average 20 percent during the first minute after release, 10 percent during the second and third minutes, and 5 percent during the fourth and fifth minutes. The standard pilot balloon properly inflated will ascend on the average during—

	Yards
First minute	240
Second minute	220
Third minute	220
Fourth minute	210
Fifth minute	210
Each subsequent minute	200

14. Inflating and weighing balloon.—*a.* Attach the coupling ML–49 to the outlet of the hydrogen cylinder. This connection should be made snug with a wrench. Slip the hose ML–81 over the end of the coupling. If the hose fits too loosely, it may be necessary to secure the hose to the coupling with several wrappings of cord. Fasten the neck of the balloon to the large end of the cock ML–56 with two light rubber bands. Roll up the balloon to expel the air from it and then close the valve of the hose cock. Expel the air from the coupling and hose by a slight rush of hydrogen from the cylinder. Slip the small end of the hose cock into the hose. All connections should be gastight; however, the connection between the hose cock and the hose should permit the ready removal of the hose cock from the hose. The balloon is now ready for inflation. Open the valve of the hose cock, and then carefully open the valve of the hydrogen cylinder and allow the balloon

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to fill slowly with hydrogen until it is approximately 25 inches in diameter. Close the valve of the hydrogen cylinder, and then close the valve of the hose cock. Detach the hose cock from the hose. The hose cock is left attached to the balloon to determine whether the balloon has been inflated to the proper free lift. Hold the balloon to the front and cautiously release it. If the balloon falls, put in more hydrogen. If the balloon rises, open the valve of the hose cock to let out some of the hydrogen. The proper free lift is obtained when weight of the hose cock balances the ascensional or lifting force of the balloon. When the balloon has been properly inflated, put two or three twists in the neck of the balloon just above the hose cock. Take this twisted part firmly between the thumb and forefinger and remove the hose cock. Turn the lower part of the neck of the balloon over the twisted part and wrap two rubber bands around the neck as many times as possible without breaking the bands. The balloon is now ready for a daylight ascension.

b. When an observation is to be made at night, paper lantern ML–91 is suspended from the balloon. Fasten candle ML–90 on the bottom of the lantern with a thumb tack. Tie a piece of cord about 6 feet long to the handle of the lantern. Inflate the balloon according to the instructions in *a* above, but weigh the balloon with the cord and lantern hanging from the hose cock. When the balloon is ready to be released, light the candle and tie the cord to the neck of the balloon. Observations are made on the lighted lantern. Open flames should be handled with special caution because of the inflammable nature of the hydrogen.

c. When the pilot balloon is inflated, weighed, and released for ascension, the temperature of the hydrogen should be approximately the temperature of the outdoor air so that the balloon will have the proper free lift when released. Therefore, a nonheated room or shelter should be used for storing the tanks of hydrogen and for inflating and weighing the balloons.

15. Tracking free balloon.—*a.* The object of tracking the free balloon is to obtain data from which to determine the wind speeds and directions for the various altitude zones. The balloon is free to move with the air; consequently, the horizontal movement of the balloon is a measure of the wind movement at the altitude of the balloon. Since the altitude of the balloon is assumed to be known at each minute after release and the angles of elevation and azimuth can be measured, the horizontal distance and direction to the balloon can be determined for each minute after release. From this a plot of

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horizontal components of the travel of the balloon can be made for successive minutes.

b. (1) With the theodolite in position and oriented, the balloon ready for ascension, and a means provided for obtaining periodic readings on the balloon and transmitting these readings to the plotter, the personnel of the meteorological station should be distributed as follows: the observer takes position at the theodolite and disengages the tangent screws; the reader takes the balloon to a position adjacent to the theodolite; the plotter takes position at the plotting board ML–122 or ML–55 for plotting the horizontal projection of the path of the balloon; and the assistant plotter takes position at plotting board ML–120 and ML–57 for plotting weighted winds.

(2) When everything is in readiness, the reader releases the balloon at time zero. When the time interval unit ML–138 is used, it should be put in operation before the balloon is released, and time zero should be made to coincide with the end of one of the tone signals. When a stop watch is used, it should be started at time zero. When a wrist watch is used, time zero should occur when the second hand is at 60. As soon as the balloon is released the reader points the theodolite at the rising balloon by means of the open sight while the observer sights through the telescope. Since the tangent screws are disengaged, the theodolite is free to rotate about its horizontal and vertical axes. When the image of the balloon appears in the telescope, the observer immediately engages both tangent screws and tracks the balloon in azimuth and elevation. He keeps the cross hairs of the telescope on or near the image of the balloon. When the reader announces "Ready," the observer, if necessary, moves the cross hairs exactly on the image of the balloon. When the reader announces "Read," the observer stops tracking momentarily so that the position data of the balloon at that instant may be ready from the theodolite scales. The reader first reads the angle of elevation and transmits it to the plotter. The reader then reads the azimuth and transmits it to the plotter. During this time the observer does not move the theodolite but he continues to watch the balloon through the instrument. The reading of the data must be done very quickly because if the balloon passes out of the field of view of the telescope, it may be very difficult to pick up the balloon again. As soon as the readings have been taken, the observer continues to track the target. This process of reading and transmitting the data is repeated every minute until the balloon is lost to view or until observations are made for 50 minutes which is the maximum time of ascent for which wind data can be determined with the present meteorological tables. It

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will be found that only occasionally is it possible to track the pilot balloon for 50 minutes.

c. If the balloon passes overhead, the observer should not allow the reading on the vertical circle to exceed 90°, but should turn the instrument through 180° in azimuth.

16. Plotting horizontal projection of travel of balloon.—*a.* (1) New type meteorological plotting equipment has been standardized recently, and there are now two different sets of equipment that may be used by the Coast Artillery Corps for plotting wind data. The two sets of equipment are listed below, new type articles opposite similar old type articles.

New equipment		*Old equipment*	
Plotting board	ML–122	Plotting board	ML–55
Rule	ML–126	Rule	ML–63
Scale	ML–125	Scale	ML–87
Plotting board	ML–120	Plotting board	ML–57
Scale	ML–125	Scale	ML–88

(2) The first three articles listed are for use in plotting the horizontal projection of the travel of the balloon and in determining the resultant wind for each altitude zone. Instructions for the use of this equipment appear in this section. The last two articles listed are for use in determining ballistic winds, and instructions for their use appear in section IV. The two sets of equipment are basically the same; however, the items of one set are not interchangeable with similar items of the other set. The general instructions for plotting apply to both types of equipment. This manual describes in detail the use of the new type plotting equipment, and refers to the old type equipment only where it is necessary to indicate differences in design or plotting procedure.

b. The new plotting equipment was designed primarily for use at mobile meteorological stations; however, in the future, this equipment will be issued also to fixed meteorological stations since no more of the old equipment is to be procured. The new plotting boards are smaller in size than the old type, and also possess several improvements in design and construction. The new scales and rules which are used in conjunction with the plotting boards also have been improved.

c. (1) The plotting board ML–122 is illustrated in figure 6, which also shows a portion of a plot. The plot is not typical, but is exaggerated for clarity. The dimensions of the board are approximately 30 by 35 inches. The surface of the plotting board consists of a paper chart sealed between two layers of a transparent material.

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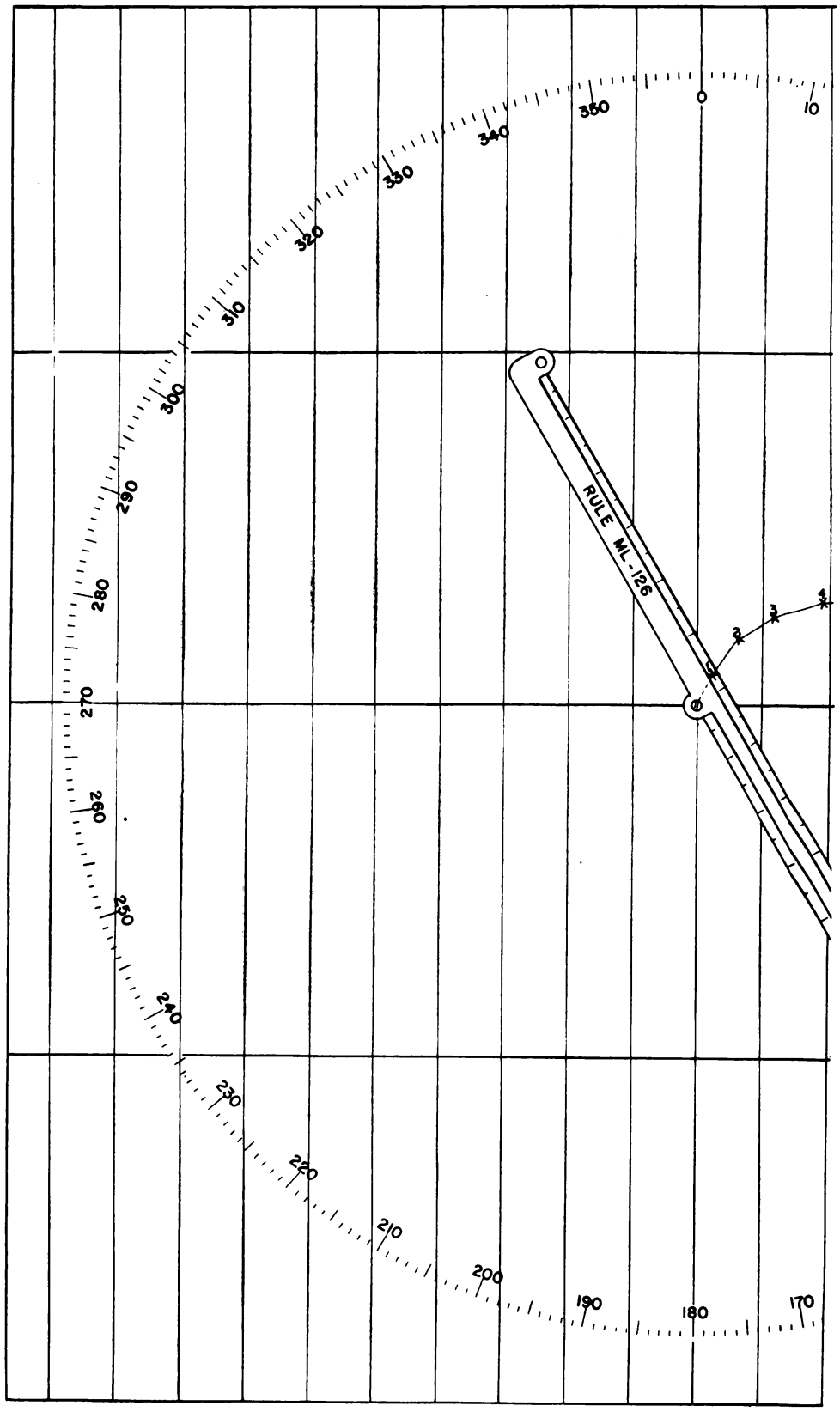


FIGURE 6.—Plotting board ML–122.

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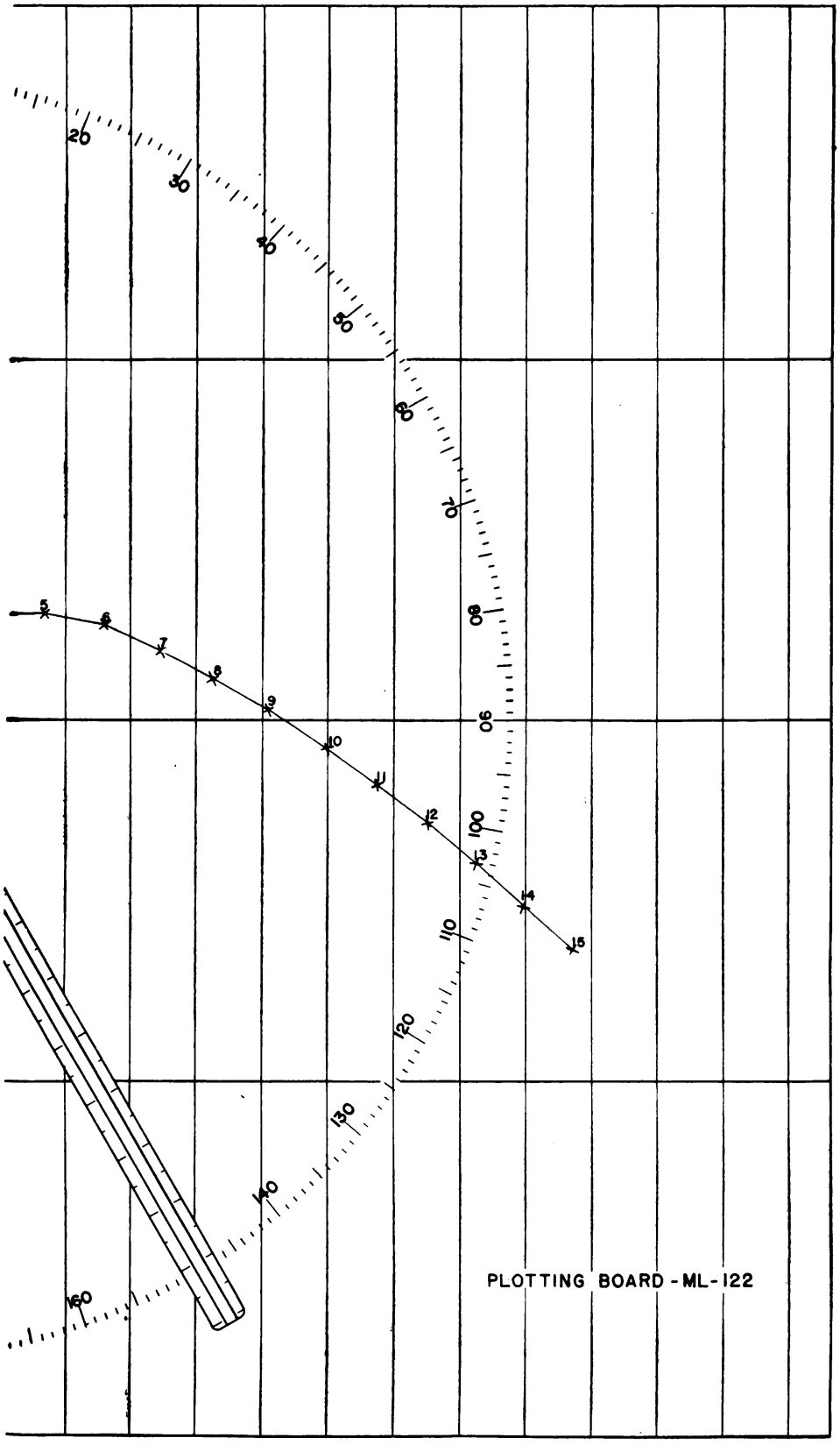


FIGURE 6.—Plotting board ML–122—Continued.

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Plots may be made on the surface with either a soft or a medium hard lead pencil. These plots may be removed with either an ordinary eraser or with art gum. The latter is preferable in that it is less abrasive and yet is very effective in removing pencil marks from the surface. With considerable use the plotting board surface will become smudged from dirt and incomplete erasures. Whenever necessary the surface should be washed with soap and water. Soap containing abrasives should not be used and no more water than necessary should be applied, particularly around the edges of the board. Excess water should be removed as promptly as possible.

(2) An azimuth circle graduated from 0° to 360° every 0.2°, and a system of vertical and horizontal lines are printed on the surface of the chart. The 0.2° graduations are not shown in figure 6. The azimuth circle is used for setting azimuths obtained from pilot balloon observations. The vertical lines are used to orient the protractor of the scale ML–125 in a north-south direction when the scale is used for evaluating wind direction data. The horizontal lines are provided so that plotting board ML–122 may be used in lieu of plotting board ML–120 whenever it is necessary or convenient to do so. (See sect. IV.)

(3) A brass pin is located at the center of the azimuth circle on the plotting board ML–122 to serve as an axis of rotation for the rule ML–126, which is a component part of the plotting board ML–122. The pin is so mounted that it may be set flush with the surface or raised to the operating position as desired. The purpose of this construction is to permit the plotting board to be used as a table surface when theodolite data are not being plotted. The pin is operated by means of a bar recessed in the under surface of the plotting board. The bar terminates at the lower edge of the plotting board. When the bar is pushed toward the pin, the pin is raised to the operating position. The pin is lowered when the bar is pulled toward the operator.

(4) The rule ML–126 is used in plotting the horizontal projections of balloon positions for each minute after release of the balloon. This is a metal rule 23 inches in length with two fiducial edges graduated in yards to a scale of 750 yards per inch for plotting horizontal distances to balloon positions. The graduations are numbered in hundreds of yards with subdivisions every 50 yards. These graduations are only indicated in figure 6 and not actually shown. Two pivot holes are provided to fit the pin at the center of the azimuth circle. The pivot hole at the end of the rule is used when the additional length of scale is needed for plotting. Zero for each scale is

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at the center of its pivot hole. The center of the azimuth circle represents the theodolite station.

d. (1) To plot the horizontal projection of the travel of the balloon, it is necessary first to determine the horizontal direction and distance to the balloon from the theodolite at each minute of the ascension. The plotter receives from the theodolite station the angle of elevation and the azimuth of the balloon and records these data immediately on W. D., Sig. C. Form No. 206 (fig. 9). The horizontal direction to the balloon is the azimuth as received from the theodolite station. The horizontal distance to the balloon may be determined by multiplying the altitude of the balloon by the cotangent of the angle of elevation of the balloon. The altitude of the balloon is known from the number of minutes that the balloon has been in the air. For example, assume that the angle of elevation as read on the theodolite at the end of the first minute is 30°. The cotangent of 30° is 1.7321. From the rate of ascent of the balloon, it is known that at the end of the first minute the balloon is at an altitude of 240 yards: therefore, the horizontal distance to the balloon is $240 \times 1.7321 = 415.7$ yards. The horizontal distance is taken to the nearest 10 yards and in this case would be recorded on W. D., Sig. C. Form No. 206 as 420 yards.

(2) The Signal Corps has prepared a set of tables, the use of which makes it unnecessary to perform the multiplication referred to above, except for ascensions beyond 30 minutes. These tables are published in TM 11–420. The number of minutes after release of the balloon and the angle of elevation of the balloon are used as arguments, and the horizontal distance to the balloon is taken directly from the table. For times of ascension above 30 minutes, it is necessary to compute the horizontal distance as explained in (1) above. TM 11–420 contains a table of cotangents for this purpose and also complete instructions for the use of all the tables therein.

e. As soon as the horizontal distance to the balloon at the end of the first minute of the ascension has been determined, the plotter records these data on W. D., Sig. C. Form No. 206, and immediately proceeds to plot this point on the plotting board. The center of the azimuth circle represents the position of the theodolite. The plotting of the point representing the horizontal projection of the position of the balloon is accomplished as follows:

(1) Set the metal rule at the azimuth to the balloon by means of the azimuth circle on the plotting board, interpolating by eye if necessary. In setting the rule, the fiducial edge which is on the same side as the pivot is used.

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(2) Along the scale on the same fiducial edge locate the horizontal distance to the balloon, interpolating by eye where necessary, and mark a cross at this point on the plotting board. Number this point to correspond to the number of minutes that the balloon has been in the air (see fig. 6).

f. Continue this process of locating points to represent the horizontal direction and distance to the balloon from the theodolite until a point has been established for each minute of the ascension. Connect successive points by straight lines to indicate the horizontal projection of the path of the balloon as illustrated in figure 6.

g. Instructions for the use of the plotting board ML–55 and the rule ML–63 are the same as the instructions appearing in *d*, *e*, and *f* above. The plotting board ML–55 has a scale of 500 yards per inch. The azimuth circle is graduated every whole degree. The use of the cross section lines in the southwest corner of the board to determine horizontal distances to pilot balloons has been discontinued.

17. Determining zone winds.—*a*. In reducing wind data to the proper form for the artillery, one of the steps is to determine the resultant wind direction and resultant wind speed for each of the standard altitude zones. The winds thus determined are called zone winds. The standard altitude zones are as follows:

Zone No.	Feet	Zone No.	Feet
1	0–600	7	9, 000–12, 000
2	0–1, 500	8	12, 000–15, 000
3	1, 500–3, 000	9	15, 000–18, 000
4	3, 000–4, 500	10	18, 000–24, 000
5	4, 500–6, 000	11	24, 000–30, 000
6	6, 000–9, 000		

b. The balloon ascends to a height of 720 feet in 1 minute; to 1,545 feet in 2¼ minutes; to 2,985 feet in 4½ minutes; to 4,500 feet in 7 minutes; and 1,500 feet higher for each additional 2½ minutes of the ascension. The wind data will be sufficiently accurate if the horizontal movement of the balloon during the first minute of the ascension is taken as the wind movement in the 0- to 600-foot zone; the horizontal movement of the balloon during the first 2¼ minutes as the wind movement in the 0- to 1,500-foot zone; the horizontal movement of the balloon during the second 2¼ minutes as the wind movement in the 1,500- to 3,000-foot zone; and the horizontal movement of the balloon during the next 2½ minutes as the wind movement in the 3,000- to 4,500-foot zone. The horizontal movement of the balloon

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during appropriate multiples of succeeding 2½-minute intervals is taken as the wind movement in subsequent zones. Points should be established therefore on the plotting board to represent the horizontal directions and distances of the balloon from the theodolite at 1, 2¼, 4½, 7, 9½, 14½, 19½, 24½, 29½, 39½, and 49½ minutes after the beginning of the ascension. The locations on the plotting board of these points are determined by interpolation, except for 1 minute and 7 minutes, between the points already established to represent the location of the balloon at the end of each minute of the ascension. These points represent approximately the horizontal projections of the positions of the balloon at the boundaries of the altitude zones.

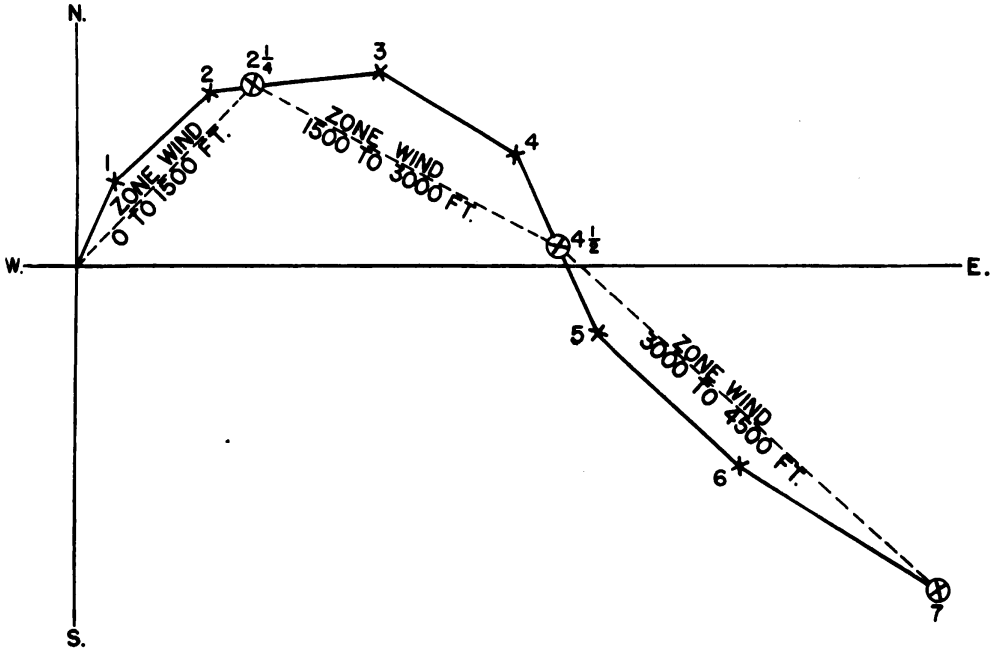


FIGURE 7.—Plot of zone winds.

As each of the points is located, it should be marked with a small cross inclosed in a circle, thus ⊕. Lines connecting these points will then represent the resultant wind in each altitude zone, or the zone wind. Figure 7 illustrates a portion of a plot of zone winds.

c. The wind direction when furnished to the artillery is expressed in hundreds of mils from north. *The direction of the wind always refers to the direction from which the wind is blowing.* The direction of a wind from the north is expressed as 6,400 mils; from the east as 1,600 mils; from the south as 3,200 mils; and from the west as 4,800 mils. Wind directions are determined to the nearest 100 mils. Wind speeds are determined in miles per hour to the nearest mile. The wind

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direction and speed for each zone are measured from the plot of zone winds on the plotting board. The scale ML–125 is used for this purpose with the plotting board ML–122, and the scale ML–87 is used with the plotting board ML–55.

d. The scale ML–125 is illustrated in figure 8. It is made of two sheets of transparent material laminated together. On the inside surface of the lower sheet there are printed a semicircular protractor for measuring wind directions, four scales for measuring wind speeds, a scale for plotting weighted wind speeds (see sec. IV), and several parallel lines for use in orienting the protractor on the plotting board. The protractor is graduated in hundreds of mils. Small holes are drilled on the circumference of the protractor at the 100-mil graduations so that the protractor may be used for plotting directions as well as measuring directions. The radial lines are 50 mils on each side of the 100-mil graduations, thus forming sectors of 100 mils. Zone wind directions are measured to the nearest 100 mils; consequently, the direction from one point to another is determined by the sector within which a line connecting these points is contained. Zone wind speeds are measured from the plotting board directly in miles per hour to the nearest mile with the appropriate wind-speed scale. Instructions for the use of the scale ML–125 appear in *e* below.

e. (1) To determine the wind direction for each altitude zone from the plotting board, place the center of the protractor of the scale ML–125 over the point representing the position of the balloon when it entered the lower limit of the altitude zone. Orient the protractor by placing the parallel lines of the scale in a north-south direction, that is, parallel to the vertical lines on the plotting board. Measure the direction to the point representing the position of the balloon when it reached the upper limit of the altitude zone by reading the value of the sector of the protractor which contains the line connecting the above points. The value thus determined is the direction of the wind for that altitude zone. When the protractor is oriented so that the semicircle of the protractor is to the right or east of its center, read the wind direction from the figures inside the semicircle. When the protractor is oriented so that the semicircle is to the left or west of its center, use the figures outside the semicircle. For example, in figure 7 the direction of the resultant wind in the first altitude zone would be measured as 4,000 mils. Care must be taken not to make an error of 3,200 mils (180°) in determining the wind direction. It should be observed that the protractor is oriented 3,200 mils from the true direction when used on the plotting board. This is done so that the wind direction determined will be the direction from which the wind

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is blowing and not the direction toward which the wind is blowing. The plotter must understand that the direction of a wind from between east and south is expressed by figures between 1,600 and 3,200 mils,

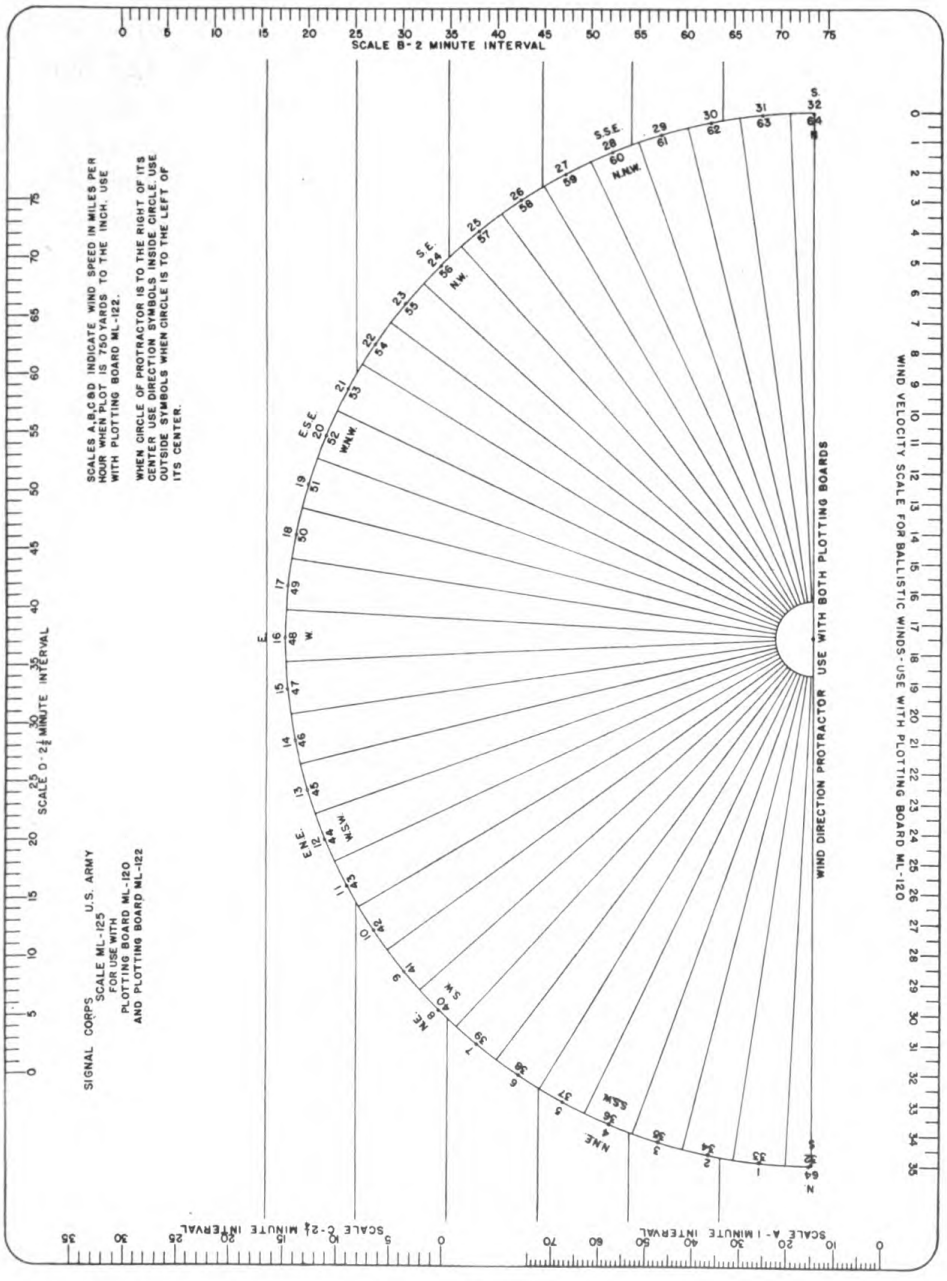


FIGURE 8.—Scale ML–125.

and the direction of a wind from between west and north is expressed by figures between 4,800 and 6,400 mils.

(2) To determine the wind speed for each altitude zone from the plotting board, measure with the proper wind speed scale the distance

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between the two points representing the positions of the balloon when it reached the lower and upper limits of the altitude zone. The wind speed scales are graduated directly in miles per hour. Use the scale which is labeled in accordance with the time interval required for the balloon to pass through the altitude zone, except for zones 6 to 11, inclusive. It requires 5 minutes for the balloon to pass through each of the zones 6, 7, 8, and 9. For measuring wind speeds in these zones, use the 2½-minute interval scale and divide the readings by two. It requires 10 minutes for the balloon to pass through each of the zones 10 and 11. For these zones, use the 2-minute interval scale and divide the readings by five, or use the 2½-minute interval scale, and divide the readings by four.

f. As soon as the plotter has determined the wind direction and speed for an altitude zone, he records these data on W. D. Sig. C. Form No. 206 and communicates these data immediately to the assistant plotter. The plotter should proceed to determine the wind for each altitude zone as soon as sufficient data are available, that is, he should begin to reduce the wind data in the lower zones to the proper form while the personnel at the theodolite station are observing the flight of the balloon in subsequent zones.

g. The above instructions, in general, for determining zone winds apply also to plotting board ML–55 and scale ML–87. The principal difference between scale ML–87 and scale ML–125 is that the radial lines of the protractor on scale ML–87 pass through the 100-mil graduations. Consequently, there are no 100-mil sectors on scale ML–87, and the direction of a line between two points is determined by the closest radial line. Scale ML–87 is not used for plotting directions.

h. When the winds are strong it sometimes happens that the plotting board is not large enough to permit the plotting of the entire horizontal projection of the travel of the balloon to the scale of the plotting board. In such cases the plotting is done to the normal scale as far as the size of the board will permit. The scale is then reduced to half the normal scale. Since all plotting for any one altitude zone must be to the same scale, it will be necessary usually to replot some of the last few normal scale points to the new scale. For example, if the plot runs off the plotting board for the twenty-second minute of the ascension, it will be necessary to replot the points for the nineteenth, twentieth, and twenty-first minutes in order to obtain the wind for the 12,000- to 15,000-foot zone. In measuring wind speeds from a plot that has been made to half scale, the wind speeds as determined by the scale ML–125 or ML–87 must be doubled.

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i. It will happen frequently that the balloon will be lost to view before it reaches the height required. In such cases, if the balloon is observed while passing through approximately one-half of any altitude zone, the position of the balloon at the top of this altitude zone should be estimated. Winds within 1,000 feet of the ground have been found to vary considerably within short distances. Winds above 1,000 feet usually do not vary greatly within distances of 25 miles over approximately level ground. The presence of hills or bodies of water will sometimes cause the wind at one place to be quite different from that a short distance away. When it is impossible to obtain data to desired heights, it is sometimes possible to supplement local data with the data from other meteorological stations. For instance, if it is impossible to observe a balloon to an altitude greater than 3,000 feet, it is justifiable to use the local data for the wind between the ground and an altitude of 3,000 feet, and to use data obtained from any meteorological station within 25 miles, or under favorable conditions within 50 miles, for the altitudes above 3,000 feet.

SECTION IV

BALLISTIC WINDS

	Paragraph
Definition and discussion	18
Wind weighting factors	19
Plotting weighted zone winds	20
Determining ballistic winds	21

18. Definition and discussion.—*a.* (1) A ballistic wind is a computed wind which would have the same effect upon a projectile as the actual winds through which the projectile passes in traveling from the gun to the target. The ballistic wind is expressed as an assumed wind of uniform direction and speed throughout the entire trajectory. A separate ballistic wind is computed for each of the following standard altitudes (see par. 2*d*):

Standard altitude No.	Height in feet	Standard altitude No.	Height in feet
1	600	7	12, 000
2	1, 500	8	15, 000
3	3, 000	9	18, 000
4	4, 500	10	24, 000
5	6, 000	11	30, 000
6	9, 000		

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(2) The standard altitudes coincide with the upper limits of correspondingly numbered altitude zones. Ballistic winds are determined by combining the various winds of the zones included in the standard altitude. Before the zone winds are combined, they are weighted proportionally to the part that each zone plays in making up the total effect of a uniform wind throughout the entire trajectory. The weighting is approximately proportional to the times that the projectile is assumed to be in the various zones during its time of flight. However, other factors are considered in weighting the zone winds.

b. (1) The results of many observations show that the wind near the ground is often considerably different from the wind in the higher zones. For instance, the data below were obtained by actual observation of a pilot balloon.

Zone winds

Zone (feet)	Direction (mils)	Speed (miles per hour)
0–1,500	3, 400	4
1,500–3,000	4, 000	14
3,000–4,500	4, 200	29
4,500–6,000	4, 500	34

(2) For the purposes of illustrating one of the necessities of weighting the zone winds, assume that a projectile in traveling from a gun to a target reaches a maximum ordinate of 6,000 feet, passes through the zone winds indicated above, and that the time of flight is 39 seconds. Assume further that 5 seconds of the time of flight are spent in the zone between 0 and 1,500 feet, 6 seconds in the zone between 1,500 and 3,000 feet, 8 seconds in the zone between 3,000 and 4,500 feet, and 20 seconds in the zone between 4,500 and 6,000 feet. This represents a typical case. The projectile will be influenced by the wind in the highest zone about four times as long as it is influenced by the wind in the lowest zone. It is evident, therefore, that the zone winds must be weighted before being combined into a ballistic wind.

19. Wind weighting factors.—*a.* The Ordnance Department has prepared wind weighting factors used for weighting the zone winds to determine ballistic winds for the various standard altitudes. The zone winds are weighted by multiplying the speeds of the zone winds by appropriate weighting factors. It was found that these weighting factors should be somewhat different for various types of guns and ammunition. However, the direction and speed of the wind are subject to considerable change during short periods of time; consequently,

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the meteorological data must be reduced to proper form and made available to the artillery with the least practicable delay. The use of several sets of weighting factors is not justified because of the additional time required to complete the computations for all guns. Any gain in accuracy will be lost if the wind changes before the data are used. It was decided therefore to provide for the computation of two sets of ballistic winds, one set for guns firing at high angles of elevation, principally antiaircraft guns, and the other set for guns firing at low angles of elevation. Two sets of wind weighting factors have been provided for this purpose, and appear in tables I and III for high-angle fire and low-angle fire, respectively. The data in tables II and IV are various wind speeds multiplied by the weighting factors appearing in tables I and III, respectively. (See instructions preceding tables II and IV.)

b. The resultant wind for the first zone (0 to 600 feet) is used as the ballistic wind for the first standard altitude (600 feet). The resultant wind for the second zone (0 to 1,500 feet) is used as the ballistic wind for the second standard altitude (1,500 feet). Consequently, tables I and III do not contain wind weighting factors for determining ballistic winds for the first and second standard altitudes. It will be noticed also that the first zone is not considered in determining ballistic winds above 600 feet. For example, to determine the ballistic wind for an altitude of 4,500 feet, the zone winds of the second (0 to 1,500 feet), third (1,500 to 3,000 feet), and fourth (3,000 to 4,500 feet) zones are weighted and combined.

20. Plotting weighted zone winds.—*a.* Ballistic winds, except those for the 600-foot and 1,500-foot standard altitudes, are determined by the assistant plotter from a plot of weighted zone winds on the plotting board ML–120 or ML–57 with the use of the scale ML–125 or ML–88, respectively. Weighted zone winds are plotted as vector quantities and the ballistic winds are determined graphically.

b. Plotting board ML–120 is approximately 30 inches square and is constructed of the same material as plotting board ML–122 described in paragraph 16*c*. The instructions for the care and maintenance of the two types of plotting boards are the same. The plotting board ML–120 is used only for determining ballistic winds and therefore is not provided with an azimuth circle. Vertical and horizontal lines are provided in the same manner as on plotting board ML–122. The vertical lines are used for orienting the protractor of scale ML–125 which is used also with plotting board ML–120. The intersections of the horizontal lines with the vertical lines form con-

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venient points from which to start plots for determining the various ballistic winds.

c. In plotting weighted zone winds on plotting board ML–120, the assistant plotter uses scale ML–125 (fig. 8) which is the same type as that used by the plotter at plotting board ML–122. The method of orienting the protractor of the scale for plotting weighted zone winds is similar to the method described in paragraph 17*e*(1). However, additional explanation is necessary to distinguish the difference between measuring directions and plotting directions. As explained in paragraph 17*e*(1), the protractor must be oriented with the parallel lines of the scale in a north-south direction. When the direction to be laid off is indicated by one of the figures inside the semicircle, the protractor must be oriented with the semicircle to the right or east of the center. When the direction to be laid off is indicated by one of the figures outside the semicircle, the protractor must be oriented with the semicircle to the left or west of the center. The required direction is laid off by placing the point of a lead pencil in the proper hole on the semicircle, thus making a pencil mark on the plotting board in the required direction from the point over which the center of the protractor rests.

d. There are 22 ballistic winds that may be determined, 11 for high-angle fire and 11 for low-angle fire, provided that wind data aloft can be obtained to 30,000 feet. It is not necessary to plot weighted zone winds to determine the ballistic winds for the first and second standard altitudes (see par. 19*b*). Therefore, the maximum number of ballistic plots required is 18, consisting of 9 for high-angle fire, and 9 for low-angle fire.

e. As explained in paragraph 17*f*, the plotter communicates the data for each zone wind to the assistant plotter as soon as that zone wind has been determined. The assistant plotter also has a W. D., Sig. C. Form No. 206 for the purpose of recording zone winds and ballistic winds. The zone winds of the first and second zones are recorded as the ballistic winds for the first and second standard altitudes, respectively. When the data for the second zone wind have been received and recorded, the assistant plotter proceeds without delay to start 18 plots for the purpose of determining 18 ballistic winds. Each of these plots is started at an intersection of a horizontal and vertical line on the plotting board. The intersections along the lower horizontal line are used for low-angle fire and those along the middle horizontal line are used for high-angle fire. The upper horizontal line is provided for plotting ballistic winds used in bombing. At coast artillery meteorological stations the latter intersections are

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surplus and may be used if additional plotting space is needed. Beginning at a convenient intersection towards the left on each hori-

Ascension No. _____

METEOROLOGICAL DATA SHEET FOR ARTILLERY

Station _____ Date _____ Starting Time _____

BALLOON ASCENSION DATA				
Minute	Altitude (yds.)	Elevation angle (degrees)	Azimuth from north (degrees)	Horizontal distance (yds.)
1	240			
2	460			
3	680			
4	890			
5	1,100			
6	1,300			
7	1,500			
8	1,700			
9	1,900			
10	2,100			
11	2,300			
12	2,500			
13	2,700			
14	2,900			
15	3,100			
16	3,300			
17	3,500			
18	3,700			
19	3,900			
20	4,100			
21	4,300			
22	4,500			
23	4,700			
24	4,900			
25	5,100			
26	5,300			
27	5,500			
28	5,700			
29	5,900			
30	6,100			
31	6,300			
32	6,500			
33	6,700			
34	6,900			
35	7,100			
36	7,300			
37	7,500			
38	7,700			
39	7,900			
40	8,100			
41	8,300			
42	8,500			
43	8,700			
44	8,900			
45	9,100			
46	9,300			
47	9,500			
48	9,700			
49	9,900			
50	10,100			

ZONE WINDS				
Time at upper limit of zone	Zone No.	Zones (feet)	Direction (Mils from North)	Speed (m.p.h.)
1	1	0- 600		
2½	2	0- 1,500		
4½	3	1,500- 3,000		
7	4	3,000- 4,500		
9½	5	4,500- 6,000		
14½	6	6,000- 9,000		
19½	7	9,000-12,000		
24½	8	12,000-15,000		
29½	9	15,000-18,000		
39½	10	18,000-24,000		
49½	11	24,000-30,000		

SURFACE DATA

Temperature _____ F.
Pressure _____ in.
Humidity _____ per cent
Density _____ per cent
Wind, speed _____ m.p.h.
Wind, azimuth _____ mils
Visibility _____
Tide _____ ft.
Station elevation _____ ft.

BALLISTIC DATA

Standard Altitude No.	Height (feet)	HIGH ANGLE FIRE			LOW ANGLE FIRE		
		Wind direction (mils)	Wind Speed (m.p.h.)	Density (percent)	Wind direction (mils)	Wind Speed (m.p.h.)	Density (per cent)
1	600						
2	1,500						
3	3,000						
4	4,500						
5	6,000						
6	9,000						
7	12,000						
8	15,000						
9	18,000						
10	24,000						
11	30,000						

METEOROLOGICAL MESSAGE

| HIGH ANGLE FIRE | | | | | |

point will depend upon the assistant plotter's estimate of the distance required for any plotting to the left of this point. This estimate should be based on the general trend of the speed and direction of the winds in the first two zones. Experience will teach the assistant plotter to establish the first starting point rapidly and correctly. The assistant plotter numbers the starting point on each of the two horizontal lines from 3 to 11, inclusive, beginning at the left. The figure 3 indicates that the plot which starts at that point is for determining the ballistic wind for the third standard altitude. The figure 4 indicates the beginning of a plot to determine the ballistic wind for the fourth standard altitude, and so on. The plotting of ballistic winds for both high- and low-angle fire is accomplished in the same manner, except that different weighting factors are used.

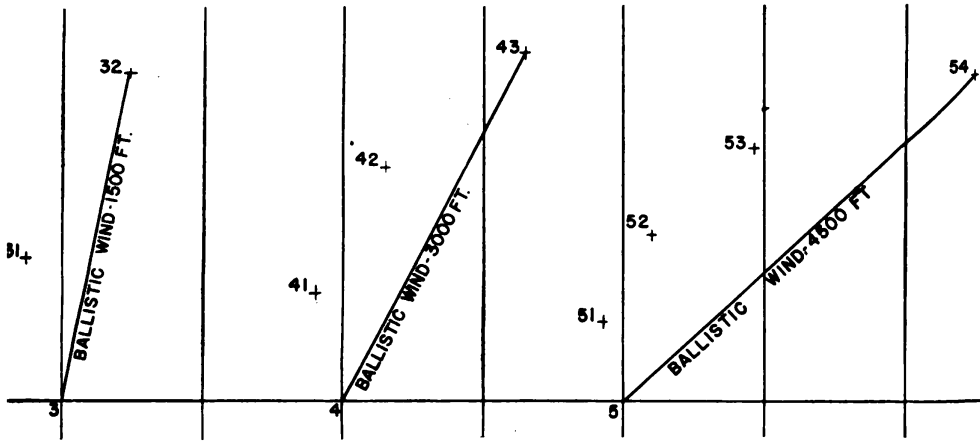


FIGURE 10.—Method of determining ballistic winds.

f. After establishing the starting points, the assistant plotter proceeds to plot the weighted zone winds. Figure 10 illustrates the method of determining the ballistic winds for the third, fourth, and fifth standard altitudes. The assistant plotter lays off from each starting point the resultant direction of the wind in the 0- to 1,500-foot zone. He uses the protractor of scale ML–125 for this purpose, and makes a pencil mark on the plotting board to indicate the required direction (see *c* above). The assistant plotter then obtains from table II the weighted wind speeds of the 0- to 1,500-foot zone for each of the ballistic winds to be determined for high-angle fire. He obtains from table IV similar data for low-angle fire. A distance representing the appropriate weighted wind speed to the nearest tenth of a mile per hour is then laid off from each starting point in the direction already established. The assistant plotter uses the graduations at the bottom of scale ML–125 for this purpose. These gradua-

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tions are in miles per hour to the nearest half mile. He uses the pencil mark referred to above to set the fiducial edge of the scale in the proper direction. At a distance representing the weighted wind speed he plots a point, interpolating if necessary. The direction and distance from each starting point to the first plotted point represent the direction and speed of the weighted wind of the 0- to 1,500-foot zone for each of the ballistic winds to be determined. The first point laid off from starting point 3 is numbered 31; the first point laid off from starting point 4 is numbered 41; and so on. These numbers correspond to the numbers appearing at the top of the columns on the first pages of tables II and IV. The direction and distance from point 3 to point 31 represent the weighted wind in the first zone of the third standard altitude; the direction and distance from point 4 to point 41 represent the weighted wind in the first zone of the fourth standard altitude; and so on. It will be noted that the 0- to 1,500-foot zone is referred to as the first zone of the third and subsequent standard altitudes.

g. The direction and distances representing the weighted winds of the 1,500- to 3,000-foot zone are next laid off from points 31, 41, 51, 61, and so on. Weighted wind speeds are obtained from the second pages of tables II and IV. The procedure of plotting the points is the same as above. The second series of plotted points thus established are numbered 32, 42, 52, 62, and so on. The direction and distance from point 31 to 32 represent the weighted wind in the second zone of the third standard altitude; the direction and distance from point 41 to point 42 represent the weighted wind in the second zone of the fourth standard altitude; and so on.

h. The assistant plotter next establishes points 43, 53, 63, 73, and so on, using weighting factors from the correspondingly numbered columns in tables II and IV. This procedure is continued until points have been established for all zone winds up to the greatest height for which data have been obtained. It will be noted on the first pages of tables II and IV that the last two columns are numbered 01 and 11 instead of 101 and 111. This is because only the last two digits of the numbers are retained for identifying the points. This principle is followed throughout the tables, and plotted points are numbered accordingly.

i. As an abbreviated example, assume it is desired to begin a plot of weighted zone winds for high-angle fire from the data appearing in paragraph 18*b*. The resultant direction and speed of the wind in the 0- to 1,500-foot zone are 3,400 mils, and 4 miles per hour, respectively. A direction of 3,400 mils is laid off from each starting

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point on the plotting board. From table II, the weighted wind speeds appearing opposite 4 in columns 31 and 41 are 2.5 and 1.6 miles per hour, respectively. Point 31 is plotted 3,400 mils in direction and 2.5 divisions in distance from point 3. Point 41 is plotted 3,400 mils in direction and 1.6 divisions in distance from point 4. Points 51, 61, and so on, are established in a similar manner. The direction and speed of the wind in the 1,500- to 3,000-foot zone are 4,000 mils and 14 miles per hour, respectively. Directions are laid off at 4,000 mils from points 31, 41, and so on. From table II, the weighted wind speeds appearing opposite 14 in columns 32 and 42 are 5.3 and 5.5 miles per hour, respectively. Point 32 is plotted 4,000 mils in direction and 5.3 divisions in distance from point 31. Point 42 is plotted 4,000 mils in direction and 5.5 divisions in distance from point 41. Points 52, 62, and so on, are established in a similar manner. This procedure is continued for subsequent points.

21. Determining ballistic winds.—*a.* It will be observed that no provision is made in table II or IV for carrying the plot started at point 3 any farther than point 32. This plot is completed by drawing a line from point 3 to point 32. (See fig. 10.) The direction and length of this line represent the direction and speed, respectively, of the ballistic wind for the third standard altitude (3,000 feet). The direction and length are measured with the scale ML–125. The protractor is oriented and the direction to the nearest 100 mils is measured in the same manner as explained in paragraph 17*e*(1). The speed is measured to the nearest mile per hour by means of the same scale used in plotting weighted wind speeds. Likewise, a line from point 4 to point 43 represents the ballistic wind for the fourth standard altitude (4,500 feet); a line from point 5 to point 54 represents the ballistic wind for the fifth standard altitude (6,000 feet); and so on. As the assistant plotter determines each ballistic wind, he records the data on W. D., Sig. C. Form No. 206.

b. As a partial illustrative example, the ballistic winds tabulated below were determined from the data appearing in paragraph 18*b*.

Standard altitude No.	Height in feet	Ballistic winds			
		For high-angle fire		For low-angle fire	
		Direction (mils)	Speed (mph)	Direction (mils)	Speed (mph)
1	3,000	3, 800	8	3, 900	10
2	4,500	4, 000	13	4, 100	18
3	6,000	4, 200	17	4, 300	22

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c. The instructions given in the above paragraphs for plotting weighted zone winds and determining ballistic winds with plotting board ML–120 and scale ML–125 apply in general to plotting board ML–57 and scale ML–88. The two types of plotting boards are the same except for material and size. Scale ML–88 is similar to scale ML–87 described in paragraph 17*g*. The radial lines of the protractor pass through the 100-mil graduations to the edges of scale ML–87. Directions are laid off by making a pencil mark at the end of the appropriate radial line. All other plotting procedure is similar to that described in this section.

SECTION V

SURFACE OBSERVATIONS

	Paragraph
Scope	22
Atmospheric pressure	23
Relative humidity	24
Air temperature	25
Surface air density	26
Surface winds	27

22. Scope.—In preparing the meteorological message for the artillery, it is necessary to determine the values of the following surface atmospheric conditions at the meteorological station: pressure, relative humidity, temperature, density, wind direction, and wind speed.

23. Atmospheric pressure.—*a.* Atmospheric pressure is the force exerted by the air due to its weight. The pressure may be expressed in terms of the height of a column of mercury of unit cross section. For example, the normal atmospheric pressure at sea level may be expressed as 29.92 inches. This means that the normal atmospheric pressure per square inch is equal to the weight of a column of mercury 29.92 inches high and 1 square inch in cross section. Atmospheric pressure is measured in inches with the barometer ML–2 or ML–9.

b. Barometer ML–2 consists of a mercurial barometer and a thermometer mounted in a case. The thermometer is used in determining the temperature corrections which must be applied to the reading of the barometer. Very accurate determinations of pressure may be obtained from the barometer ML–2. A vernier is provided for obtaining readings to the nearest 0.002 inch. This is a direct vernier similar to the theodolite vernier discussed in paragraph 9*e* and illustrated in figure 4. The smallest graduation on the main scale of the barometer is 0.05 inch. The smallest graduation on the vernier

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is 0.002 inch. The vernier is read in the same manner as the theodolite vernier.

c. To determine the atmospheric pressure with barometer ML–2 proceed as follows:

(1) Read the attached thermometer to the nearest 0.5 degree.

(2) By means of the thumbscrew at the bottom of the barometer, adjust the top surface of the mercury in the cistern so that the mercury just touches the ivory pointer suspended from the top of the cistern.

(3) Tap the side of the barometer very gently with the finger. Adjust the vernier of the barometer so that the index at the bottom of the vernier is level with the top of the meniscus or convex surface of the mercury column.

(4) Read the barometer to the nearest 0.002 inch and record the reading on an improvised form.

(5) Reduce the barometer reading to conditions of standard gravity and temperature. Each mercurial barometer is provided with two types of correction cards, W. D., Sig. C. Form No. 79 (Barometric Corrections) and W. D., Sig. C. Form No. 80 (Corrections of Mercurial Barometer for Temperature). On Form No. 79 appears a correction marked "Sum of gravimetric and instrumental corrections" which must be applied to all readings made with that barometer. The correction applies only to a particular barometer located at a particular place. Form No. 80 contains a table of corrections for temperature. The following example illustrates the method of applying the necessary corrections to the barometer reading:

Attached thermometer reading	72.0° F.
	Inches
Observed barometer reading	30.328
	Inch
Correction from Form No. 79	−0.008
Temperature correction from Form No. 80	−.119
Total correction	−.127
Corrected barometer reading	30.201

Record the corrected barometer reading to the nearest 0.01 inch on W. D., Sig. C. Form No. 206 as the atmospheric pressure.

d. Barometer ML–2 is very fragile and expensive and must be handled with extreme care. For this reason it is issued only to fixed

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meteorological stations where it is mounted securely to the wall. It should never be removed from the wall by personnel serving at the station. Installation and removal of mercurial barometers should be performed by the harbor defense artillery engineer or by a representative of the Signal Corps.

e. Barometer ML–9 is an aneroid barometer. It is comparatively rugged and is issued to both fixed and mobile meteorological stations. However, it must be handled with care. Although barometer ML–9 is not as accurate as barometer ML–2 it will give satisfactory results for the purposes intended if it is kept in adjustment. The aneroid barometer should be checked with a mercurial barometer whenever the opportunity arises. Adjustments may be made by means of a screw in the back of the barometer case.

f. To determine the atmospheric pressure with barometer ML–9, tap the instrument lightly with the finger and read from the scale the position of the pointer to the nearest 0.01 inch. Record this reading on W. D., Sig. C. Form No. 206, as the atmospheric pressure. No corrections of the reading are necessary.

24. Relative humidity.—*a.* The relative humidity is the ratio of the actual amount of water vapor present in the atmosphere to the greatest amount possible at the same temperature. This ratio is expressed in percent. The relative humidity at the meteorological station is determined with the psychrometer ML–24. The relative humidity of saturated air is 100 percent.

b. Psychrometer ML–24 consists of two identical mercurial thermometers mounted beside each other on an aluminum frame. The thermometers are graduated in degress Fahrenheit. The frame is attached to a wooden handle by a chain linkage. The bulbs of the thermometers project beyond the frame. The bulb of one thermometer is covered with a single thickness of cloth called a wick. This thermometer is called the wet-bulb thermometer. The other thermometer is called the dry-bulb thermometer. To determine the relative humidity proceed as follows:

(1) Saturate the wick on the bulb of the wet-bulb thermometer with water of the same temperature as the atmosphere. Do not wet the bulb of the other thermometer.

(2) Stand in an open space in the shade and, holding the psychrometer by the handle, whirl the instrument rapidly for about 30 seconds. (A simple motion of the wrist is all that is necessary.) Note the reading of the wet-bulb thermometer. Repeat this operation until two consecutive readings are the same. Record on an improvised form the readings of both the wet-bulb and dry-bulb

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thermometers at this time to the nearest 0.5 degree. Subtract the reading of the wet-bulb thermometer from that of the dry-bulb thermometer. This difference is called the depression of the wet-bulb thermometer. The reading of the dry-bulb thermometer is the air temperature.

(3) Enter table VI with the depression of the wet-bulb thermometer and the air temperature as arguments, and obtain the value of the relative humidity to the nearest whole percent, interpolating where necessary. The following example illustrates the method of determining the relative humidity from the psychrometer readings:

Air temperature (reading of dry-bulb thermometer)	68.0°
Reading of wet-bulb thermometer	59.5°
Depression of wet-bulb thermometer	8.5°
Relative humidity from table VI	60 percent

Record the relative humidity on W. D., Sig. C. Form No. 206.

25. Air temperature.—The temperature of the air is the reading obtained from the dry-bulb thermometer of the psychrometer when the readings for determining relative humidity are taken. This temperature is recorded on W. D., Sig. C. Form No. 206 to the nearest whole degree. The reading of the thermometer attached to barometer ML–2 should *not* be taken as the outside air temperature.

26. Surface air density.—*a.* Air density is a measure of the weight of the air per unit volume. For artillery purposes the air density at a particular altitude is expressed in percent of the standard artillery air density at that altitude. The standard artillery air density is 525.9 grains per cubic foot at the surface and is assumed to decrease in a particular manner with altitude. (See table V.) The air density depends on the temperature and pressure of the atmosphere and to a lesser extent on the relative humidity. Dry air has a somewhat greater density than moist air of the same temperature and pressure.

b. The surface air density at the meterological station is determined from the values of temperature, pressure, and relative humidity. Tables VII and VIII contain the necessary data for the rapid determination of air density under atmospheric conditions likely to be encountered. Table VII contains values of air densities for various values of atmospheric pressure and temperature when the relative humidity is 78 percent. Table VIII contains corrections

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to be applied to the results obtained from table VII when the relative humidity is other than 78 percent. Interpolation is performed in both tables where necessary. The surface air density is determined to the nearest whole percent and recorded on W. D., Sig. C. Form No. 206.

c. The example given below illustrates the method of determining surface air densities. Assume that the following results are obtained from the surface observations:

Air temperature	74° F.
Atmospheric pressure	29.94 inches
Relative humidity	42 percent

The air density value as obtained from table VII is 98.3 percent; however, this result must be corrected for a relative humidity of 42 percent. From table VIII this correction is obtained as plus 0.4 percent. The correct air density therefore is 98.7 percent. This value is recorded as 99 percent.

27. Surface winds.—*a.* At harbor defense meteorological stations the direction of the surface wind is estimated in hundreds of mils by means of a wind vane mounted on support ML–29A, and the speed of the surface wind is measured to the nearest mile per hour with the anemometer ML–13 or ML–58 and the buzzer box ML–82. The wind vane and anemometer are permanently installed at the station and exposed to the wind from any direction. The center of the roof of a flat-top building is usually a satisfactory location for the installation of the wind vane and anemometer.

(1) The wind vane is positioned by the wind, and the direction toward which the wind vane points is the direction from which the wind is blowing. Only four direction arms indicating north, south, east, and west are provided to show the direction of the wind; consequently, an observer must estimate the direction in hundreds of mils. To do so he takes position as nearly directly under the wind vane as possible and notes its position relative to the direction arms. North is designated as 6,400 mils; east, 1,600 mils; south 3,200 mils; and west, 4,800 mils. There are times when the wind direction is difficult to estimate because of the rapid fluctuation of the surface wind. In such cases the mean of the various directions observed over a period of 1 minute should be estimated.

(2) Anemometers ML–13 and ML–58 are basically the same. Each type of anemometer consists principally of four hemispherical cups mounted on cross arms at right angles to each other. Wind movement causes the cups to rotate about a vertical axis. This rota-

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tion operates a series of electrical contacts in a circuit containing buzzer box ML-82. When the anemometer is operating and the push button on the buzzer box is held in, a series of short buzzes are heard. The number of buzzes per minute is the speed of the surface wind in miles per hour. The observation should be made over a period of 2 minutes, beginning at the end of a tone signal, and the number of tone signals divided by two. The speed of the surface wind is recorded on W. D., Sig. C. Form No. 206. The anemometer should be oiled once a week.

b. Anemometers and wind vanes are not yet provided for mobile meteorological stations. Without such instruments, surface winds at these stations are determined from a theodolite observation of a balloon 15 seconds after its release. This observation is made at the beginning of the balloon ascension for determining winds aloft. The horizontal projection of the position of the balloon at the end of 15 seconds is determined and plotted in the same manner as explained in paragraph 16. In 15 seconds the balloon rises approximately 65 yards. The cotangent of the angle of elevation must be used to determine the horizontal distance. The direction and speed of the wind is determined in the same manner as explained in paragraph 17. The wind-speed scale for the one minute interval is used and the results multiplied by four, or the horizontal distance from the theodolite to the balloon may be plotted to four times its calculated length and the wind speed measured directly with the 1-minute interval scale.

SECTION VI

BALLISTIC DENSITIES

Paragraph
Definition and discussion 28
Determining ballistic densities 29

28. Definition and discussion.—*a.* A ballistic density is a computed air density which would have the same effect on a projectile as the actual air densities through which the projectile passes in traveling from the gun to the target. The relation between a ballistic density and the actual air densities is similar to the relation between a ballistic wind and the actual winds. A review of the subject matter appearing in paragraphs 18 and 19 will serve as a guide to the understanding of the meaning of ballistic density. The altitude zones and the standard altitudes used in determining ballistic winds are used also in determining ballistic densities, with the exception that the second altitude zone is 600 to 1,500 feet.

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b. The equipment at present issued to coast artillery meteorological stations provides for the determination of surface air densities, but not for the determination of air densities aloft. Consequently, the ballistic densities must be determined from the surface observations. It is assumed that actual air densities decrease in a particular manner with increase in altitude above the station, and that the rate of decrease varies with the surface air density and the height of the meteorological station above sea level. Based on the above assumptions, it is possible to determine from the surface air density the average air density for each altitude zone. The zone air densities may be multiplied by appropriate weighting factors and combined into ballistic densities. Tables IX and XI contain air density weighting factors for high-angle and low-angle fire, respectively. The average air density of each zone may be expressed in percent of the average standard artillery air density for that zone. The variation in standard artillery air density with altitude is shown in table V. The ballistic densities, therefore, may be calculated in terms of percent.

29. Determining ballistic densities.—*a.* The actual calculation of ballistic densities by the method referred to in paragraph 28*b* is lengthy and laborious. Consequently, these calculations have been performed for atmospheric conditions likely to be encountered, and the results have been compiled into tables X and XII for high-angle and low-angle fire, respectively. In order to determine from these tables the ballistic densities for all the standard altitudes, it is necessary merely to know the surface air density at the meteorological station and the height of the station above sea level. The arguments used in entering the tables are the surface air density to the nearest whole percent, and the height of the meteorological station above sea level to the nearest 100 feet. (See instructions preceding each table.) The ballistic densities in tables X and XII have been computed for meteorological stations located at sea level, 1,000 feet above sea level, and 2,000 feet above sea level. The ballistic densities are arranged in the tables in vertical groups. The first figure of each group is the surface air density at the meteorological station. If the elevation of the station to the nearest 100 feet is between 0 and 1,000 feet or between 1,000 and 2,000 feet above sea level, the ballistic densities are found by interpolation between appropriate columns. If the elevation is more than 2,000 feet above sea level, the data for 2,000 feet are used.

b. As an illustrative example, assume that the elevation of a meteorological station is 1,625 feet above sea level, and that the

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surface air density as recorded from surface observations is 99 percent. The elevation of the station to the nearest 100 feet is 1,600 feet. Interpolating between appropriate columns in tables X and XII, the following ballistic densities are found:

Standard altitude No.	Height in feet	Ballistic densities in percent		Standard altitude No.	Height in feet	Ballistic densities in percent	
		For high-angle fire	For low-angle fire			For high-angle fire	For low-angle fire
0	Surface	99. 0	99. 0	6	9,000	98. 4	98. 1
1	600	98. 9	98. 9	7	12,000	98. 2	98. 0
2	1,500	98. 8	98. 8	8	15,000	98. 1	97. 8
3	3,000	98. 7	98. 6	9	18,000	98. 0	97. 7
4	4,500	98. 6	98. 5	10	24,000	97. 8	97. 4
5	6,000	98. 5	98. 4	11	30,000	97. 5	96. 8

Ballistic densities are recorded on W. D., Sig. C. Form No. 206 to the nearest whole percent.

Section VII

METEOROLOGICAL MESSAGE

Paragraph
Encoding 30
Distribution 31

30. Encoding.—*a.* After the meteorological observations have been made and the necessary data have been determined for the artillery, these data must be made available to the artillery units with as little delay as possible. The necessary data, therefore, are sent to the artillery in the form of a concise encoded message. The plotter is responsible for consolidating all data on W. D., Sig. C. Form No. 206 and encoding the message.

b. The complete encoded meteorological message consists of two messages: message 2 and message 3. Message 2 contains meteorological data for high-angle fire. Message 3 contains meteorological data for low-angle fire. The two messages are based on the same meteorological observations, but the computed values reported in the two messages are somewhat different because different weighting factors have been applied to the basic data in order to make them applicable to the two types of gunfire.

c. The two messages are similar in appearance (see meteorological message in *i* (3) below). The first line of each message consists of three letters which are repeated, such as MFMMFM. Immediately

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below this line are 13 groups of figures. The first group contains five digits, and each subsequent group contains seven digits. The letters and each digit or pair of digits have a significant meaning.

d. The three letters are the code designation of the meteorological station where the message originated. For example, MFM is the code designation of the meteorological station at Fort Monroe, Va.

e. The five-digit group has the following significance: The first digit designates the type of message. The figure 2 indicates that the data which follow are for high-angle fire. The figure 3 indicates that the data which follow are for low-angle fire. The second and third digits in each message indicate the elevation of the meteorological station in hundreds of feet above sea level. The last two digits indicate the air temperature at the meteorological station to the nearest degree Fahrenheit. Temperatures of 100° F. and above are expressed by the last two digits of the temperature value. If the temperature is negative, the artillery should be so informed.

f. The first seven-digit group contains surface data. The first digit is 0, which indicates that the data in this group are surface data at the level of the meteorological station. The second and third digits indicate the direction from which the wind is blowing in hundreds of mils from north. The fourth and fifth digits indicate the speed of the wind in miles per hour. The sixth and seventh digits indicate the air density in percent to the nearest whole percent. When the air density is 100 percent or more, only the last two digits are included in the message. For example, an air density of 105 percent is indicated as 05.

g. Each of the subsequent seven-digit groups contains ballistic wind and density data for a particular standard altitude. The first digit of each of these groups indicates the number of the standard altitude zone to which the data in that group apply. For example, the digit 4 indicates that the data in that group apply to the fourth standard altitude (4,500 feet). The tenth and eleventh standard altitudes are indicated by the digits 0 and 1, respectively, which are the same digits used to indicate the surface and the first standard altitude. No confusion should result from this usage, since the positions of the last two groups in the message indicate clearly the standard altitudes to which they apply. The second and third digits indicate the direction of the ballistic wind in hundreds of mils. The fourth and fifth digits indicate the speed of the ballistic wind in miles per hour. The sixth and seventh digits indicate the ballistic density in percent.

h. In the event that certain data are not available, the digits representing these data are replaced by the letter "X". For example, if the

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ballistic wind data are not available for the ninth standard altitude, this would be indicated as follows: 9XXXX04.

i. The following example illustrates the encoding of a complete meteorological message. Assume that the following results are obtained from meteorological observations made at Fort Monroe, Va.

Elevation of meteorological station ..... 36 feet.
Surface data:
Air temperature ..... 40° F.
Wind direction ..... 2,300 mils
Wind speed ..... 9 mph
Air density ..... 106 percent

(1) Ballistic data for high-angle fire:

Standard altitude No.	Height in feet	Wind direction in mils	Wind speed in mph	Density in percent	Standard altitude No.	Height in feet	Wind direction in mils	Wind speed in mph.	Density in percent
1	600	2, 400	18	106	7	12, 000	3, 400	22	105
2	1, 500	2, 500	22	106	8	15, 000	3, 600	24	105
3	3, 000	2, 600	21	106	9	18, 000	3, 700	26	104
4	4, 500	2, 700	20	106	10	24, 000	3, 900	29	104
5	6, 000	2, 800	20	105	11	30, 000	4, 000	31	104
6	9, 000	3, 100	21	105					

(2) Ballistic data for low-angle fire:

Standard altitude No.	Height in feet	Wind direction in mils	Wind speed in mph.	Density in percent	Standard altitude No.	Height in feet	Wind direction in mils.	Wind speed in mph	Density in percent
1	600	2, 400	18	106	7	12, 000	3, 700	25	104
2	1, 500	2, 500	22	106	8	15, 000	3, 800	28	104
3	3, 000	2, 600	20	106	9	18, 000	3, 900	30	104
4	4, 500	2, 700	20	105	10	24, 000	4, 000	32	103
5	6, 000	3, 000	22	105	11	30, 000	4, 100	35	103
6	9, 000	3, 500	22	105					

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(3) The completely encoded message is shown below:

Meteorological Message

Message 2 for high-angle fire

M	F	M	M	F	M	–
2	0	0	4	0	–	–
0	2	3	0	9	0	6
1	2	4	1	8	0	6
2	2	5	2	2	0	6
3	2	6	2	1	0	6
4	2	7	2	0	0	6
5	2	8	2	0	0	5
6	3	1	2	1	0	5
7	3	4	2	2	0	5
8	3	6	2	4	0	5
9	3	7	2	6	0	4
0	3	9	2	9	0	4
1	4	0	3	1	0	4

Message 3 for low-angle fire

M	F	M	M	F	M	–
3	0	0	4	0	–	–
0	2	3	0	9	0	6
1	2	4	1	8	0	6
2	2	5	2	2	0	6
3	2	6	2	0	0	6
4	2	7	2	0	0	5
5	3	0	2	2	0	5
6	3	5	2	2	0	5
7	3	7	2	5	0	4
8	3	8	2	8	0	4
9	3	9	3	0	0	4
0	4	0	3	2	0	3
1	4	1	3	5	0	3

31. Distribution.—*a.* As soon as the meteorological message has been encoded, it should be distributed to the artillery units without delay. The method of distribution will be prescribed by the harbor defense commander or by the regimental commander. Distribution may be accomplished by messenger, telephone, teletype, or radio.

b. It is important that the entire procedure of making the meteorological observations, reducing the data to proper form, and transmitting the meteorological message to the artillery be completed in as short a time as practicable, since atmospheric conditions are subject to considerable change during short periods of time. For this reason all operations performed at the meteorological station should be in progress concurrently as far as practicable. During periods that the artillery is required to be in readiness for firing, a new meteorological message should be prepared and distributed once every 3 hours, or more often if necessary or desirable.

c. Under ordinary conditions, if the maximum ordinate reached by projectiles is 3,000 feet or higher, meteorological observations made within 25 miles of the firing battery generally will furnish satisfactory data. If the maximum ordinate reached by projectiles is under 1,000 feet, the meteorological observations should be made as near the firing battery as practicable.

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APPENDIX I

METEOROLOGICAL TABLES

Tables II, IV, VI, VII, VIII, X, and XII are actually used at the meteorological station in the preparation of the meteorological message. Tables I, III, V, IX, XI, and XIII are included for information. Tables I, II, IX, and X apply only to high-angle fire. Tables III, IV, XI, and XII apply only to low-angle fire. Tables V to VIII, inclusive, apply to both high- and low-angle fire.

TABLE I.—Wind weighting factors for antiaircraft and other high-angle fire.

II.—Weighted wind speeds for antiaircraft and other high-angle fire.

III.—Wind weighting factors for low-angle fire.

IV.—Weighted wind speeds for low-angle fire.

V.—Standard artillery air temperatures and densities at the midpoint of the altitude zones.

VI.—Relative humidity in percent of saturation.

VII.—Air density in percent of standard when relative humidity is 78 percent.

VIII.—Air density corrections to be applied to table VII when relative humidity is other than 78 percent.

IX.—Air density weighting factors for antiaircraft and other high-angle fire.

X.—Ballistic densities in percent of standard for antiaircraft and other high-angle fire.

XI.—Air density weighting factors for low-angle fire.

XII.—Ballistic densities in percent of standard for low-angle fire.

XIII.—Meteorological equipment and supplies.

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TABLE I.—*Wind weighting factors for antiaircraft and other high-angle fire*

Standard altitude (feet)	Zones									
	0 to 1,500	1,500 to 3,000	3,000 to 4,500	4,500 to 6,000	6,000 to 9,000	9,000 to 12,000	12,000 to 15,000	15,000 to 18,000	18,000 to 24,000	24,000 to 30,000
600 [1]	------	------	------	------	------	------	------	------	------	------
1,500 [2]	------	------	------	------	------	------	------	------	------	------
3,000	0. 62	0. 38	------	------	------	------	------	------	------	------
4,500	. 41	. 39	0. 20	------	------	------	------	------	------	------
6,000	. 31	. 31	. 27	0. 11	------	------	------	------	------	------
9,000	. 20	. 22	. 20	. 19	0. 19	------	------	------	------	------
12,000	. 15	. 16	. 15	. 16	. 27	0. 11	------	------	------	------
15,000	. 12	. 13	. 12	. 13	. 24	. 18	0. 08	------	------	------
18,000	. 10	. 11	. 10	. 10	. 21	. 20	. 12	0. 06	------	------
24,000	. 07	. 08	. 08	. 08	. 16	. 15	. 14	. 13	0. 11	------
30,000	. 06	. 06	. 07	. 06	. 13	. 13	. 12	. 11	. 18	0. 08

[1] Use wind during first minute of balloon ascension.
[2] Use wind during first 2¼ minutes of balloon ascension.

NOTE.—The above wind weighting factors were furnished by the Ordnance Department. These wind weighting factors are used in the preparation of table II. Table II is used in preparing "message 2."

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INSTRUCTIONS FOR USING TABLE II

Table II is used by the assistant plotter at plotting board ML–120 or ML–57 in determining ballistic winds for "message 2." The use of table II eliminates the necessity of multiplying the speed of the zone winds by the weighting factors in table I.

The argument in the first column is the wind speed in miles per hour for the zone indicated at the top of each page. Under the heading "Point," there is a figure of two digits at the top of each column. The first digit is the number of the standard altitude; the second digit is the number of the zone, as indicated at the top of the page. For example, the column headed "31" contains weighted wind speeds for the first zone of the third standard altitude; the column headed "54" contains weighted wind speeds for the fourth zone of the fifth standard altitude.

The following example illustrates the use of table II: the plotter reports a resultant wind speed of 22 miles per hour for the second altitude zone (0 to 1,500 feet). The assistant plotter records these data, and turns to the page which has the 0- to 1,500-foot zone indicated at the top. Opposite 22, on the same horizontal line under points 31, 41, 51, 61, and so on, he reads the following: 13.6, 9.0, 6.8, 4.4, and so on. These figures represent the weighted wind speeds in miles per hour for the first zone of the third, fourth, fifth, sixth, and so on, standard altitudes. The values are used in plotting points 31, 41, 51, 61, and so on. Weighted winds are plotted to the nearest tenth of a mile per hour.

Table II is computed for zone wind speeds of even numbers of miles per hour only. When the zone wind speed is an odd number of miles per hour, it will be necessary to interpolate.

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TABLE II.– *Weighted wind speeds for antiaircraft and other high-angle fire*

FOR ZONE 0–1,500 FEET

Speed	Point								
	31	41	51	61	71	81	91	01	11
2	1. 2	0. 8	0. 6	0. 4	0. 3	0. 2	0. 2	0. 1	0. 1
4	2. 5	1. 6	1. 2	. 8	. 6	. 5	. 4	. 3	. 2
6	3. 7	2. 5	1. 9	1. 2	. 9	. 7	. 6	. 4	. 4
8	5. 0	3. 3	2. 5	1. 6	1. 2	1. 0	. 8	. 6	. 5
10	6. 2	4. 1	3. 1	2. 0	1. 5	1. 2	1. 0	. 7	. 6
12	7. 4	4. 9	3. 7	2. 4	1. 8	1. 4	1. 2	. 8	. 7
14	8. 7	5. 7	4. 3	2. 8	2. 1	1. 7	1. 4	1. 0	. 8
16	9. 9	6. 6	5. 0	3. 2	2. 4	1. 9	1. 6	1. 1	1. 0
18	11. 2	7. 4	5. 6	3. 6	2. 7	2. 2	1. 8	1. 3	1. 1
20	12. 4	8. 2	6. 2	4. 0	3. 0	2. 4	2. 0	1. 4	1. 2
22	13. 6	9. 0	6. 8	4. 4	3. 3	2. 6	2. 2	1. 5	1. 3
24	14. 9	9. 8	7. 4	4. 8	3. 6	2. 9	2. 4	1. 7	1. 4
26	16. 1	10. 7	8. 1	5. 2	3. 9	3. 1	2. 6	1. 8	1. 6
28	17. 4	11. 5	8. 7	5. 6	4. 2	3. 4	2. 8	2. 0	1. 7
30	18. 6	12. 3	9. 3	6. 0	4. 5	3. 6	3. 0	2. 1	1. 8
32	19. 8	13. 1	9. 9	6. 4	4. 8	3. 8	3. 2	2. 2	1. 9
34	21. 1	13. 9	10. 5	6. 8	5. 1	4. 1	3. 4	2. 4	2. 0
36	22. 3	14. 8	11. 2	7. 2	5. 4	4. 3	3. 6	2. 5	2. 2
38	23. 6	15. 6	11. 8	7. 6	5. 7	4. 6	3. 8	2. 7	2. 3
40	24. 8	16. 4	12. 4	8. 0	6. 0	4. 8	4. 0	2. 8	2. 4
42	26. 0	17. 2	13. 0	8. 4	6. 3	5. 0	4. 2	2. 9	2. 5
44	27. 3	18. 0	13. 6	8. 8	6. 6	5. 3	4. 4	3. 1	2. 6
46	28. 5	18. 9	14. 3	9. 2	6. 9	5. 5	4. 6	3. 2	2. 8
48	29. 8	19. 7	14. 9	9. 6	7. 2	5. 8	4. 8	3. 4	2. 9
50	31. 0	20. 5	15. 5	10. 0	7. 5	6. 0	5. 0	3. 5	3. 0
52	32. 2	21. 3	16. 1	10. 4	7. 8	6. 2	5. 2	3. 6	3. 1
54	33. 5	22. 1	16. 7	10. 8	8. 1	6. 5	5. 4	3. 8	3. 2
56	34. 7	23. 0	17. 4	11. 2	8. 4	6. 7	5. 6	3. 9	3. 4
58	36. 0	23. 8	18. 0	11. 6	8. 7	7. 0	5. 8	4. 1	3. 5
60	37. 2	24. 6	18. 6	12. 0	9. 0	7. 2	6. 0	4. 2	3. 6
62	38. 4	25. 4	19. 2	12. 4	9. 3	7. 4	6. 2	4. 3	3. 7
64	39. 7	26. 2	19. 8	12. 8	9. 6	7. 7	6. 4	4. 5	3. 8
66	40. 9	27. 1	20. 5	13. 2	9. 9	7. 9	6. 6	4. 6	4. 0
68	42. 2	27. 9	21. 1	13. 6	10. 2	8. 2	6. 8	4. 8	4. 1
70	43. 4	28. 7	21. 7	14. 0	10. 5	8. 4	7. 0	4. 9	4. 2
72	44. 6	29. 5	22. 3	14. 4	10. 8	8. 6	7. 2	5. 0	4. 3
74	45. 9	30. 3	22. 9	14. 8	11. 1	8. 9	7. 4	5. 2	4. 4
76	47. 1	31. 2	23. 6	15. 2	11. 4	9. 1	7. 6	5. 3	4. 6
78	48. 4	32. 0	24. 2	15. 6	11. 7	9. 4	7. 8	5. 5	4. 7
80	49. 6	32. 8	24. 8	16. 0	12. 0	9. 6	8. 0	5. 6	4. 8

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TABLE II.—*Weighted wind speeds for antiaircraft and other high-angle fire*—Con.

FOR ZONE 1,500–3,000 FEET

Speed	Point								
	32	42	52	62	72	82	92	02	12
2	0.8	0.8	0.6	0.4	0.3	0.3	0.2	0.2	0.1
4	1.5	1.6	1.2	.9	.6	.5	.4	.3	.2
6	2.3	2.3	1.9	1.3	1.0	.8	.7	.5	.4
8	3.0	3.1	2.5	1.8	1.3	1.0	.9	.6	.5
10	3.8	3.9	3.1	2.2	1.6	1.3	1.1	.8	.6
12	4.6	4.7	3.7	2.6	1.9	1.6	1.3	1.0	.7
14	5.3	5.5	4.3	3.1	2.2	1.8	1.5	1.1	.8
16	6.1	6.2	5.0	3.5	2.6	2.1	1.8	1.3	1.0
18	6.8	7.0	5.6	4.0	2.9	2.3	2.0	1.4	1.1
20	7.6	7.8	6.2	4.4	3.2	2.6	2.2	1.6	1.2
22	8.4	8.6	6.8	4.8	3.5	2.9	2.4	1.8	1.3
24	9.1	9.4	7.4	5.3	3.8	3.1	2.6	1.9	1.4
26	9.9	10.1	8.1	5.7	4.2	3.4	2.9	2.1	1.6
28	10.6	10.9	8.7	6.2	4.5	3.6	3.1	2.2	1.7
30	11.4	11.7	9.3	6.6	4.8	3.9	3.3	2.4	1.8
32	12.2	12.5	9.9	7.0	5.1	4.2	3.5	2.6	1.9
34	12.9	13.3	10.5	7.5	5.4	4.4	3.7	2.7	2.0
36	13.7	14.0	11.2	7.9	5.8	4.7	4.0	2.9	2.2
38	14.4	14.8	11.8	8.4	6.1	4.9	4.2	3.0	2.3
40	15.2	15.6	12.4	8.8	6.4	5.2	4.4	3.2	2.4
42	16.0	16.4	13.0	9.2	6.7	5.5	4.6	3.4	2.5
44	16.7	17.2	13.6	9.7	7.0	5.7	4.8	3.5	2.6
46	17.5	17.9	14.3	10.1	7.4	6.0	5.1	3.7	2.8
48	18.2	18.7	14.9	10.6	7.7	6.2	5.3	3.8	2.9
50	19.0	19.5	15.5	11.0	8.0	6.5	5.5	4.0	3.0
52	19.8	20.3	16.1	11.4	8.3	6.8	5.7	4.2	3.1
54	20.5	21.1	16.7	11.9	8.6	7.0	5.9	4.3	3.2
56	21.3	21.8	17.4	12.3	9.0	7.3	6.2	4.5	3.4
58	22.0	22.6	18.0	12.8	9.3	7.5	6.4	4.6	3.5
60	22.8	23.4	18.6	13.2	9.6	7.8	6.6	4.8	3.6
62	23.6	24.2	19.2	13.6	9.9	8.1	6.8	5.0	3.7
64	24.3	25.0	19.8	14.1	10.2	8.3	7.0	5.1	3.8
66	25.1	25.7	20.5	14.5	10.6	8.6	7.3	5.3	4.0
68	25.8	26.5	21.1	15.0	10.9	8.8	7.5	5.4	4.1
70	26.6	27.3	21.7	15.4	11.2	9.1	7.7	5.6	4.2
72	27.4	28.1	22.3	15.8	11.5	9.4	7.9	5.8	4.3
74	28.1	28.9	22.9	16.3	11.8	9.6	8.1	5.9	4.4
76	28.9	29.6	23.6	16.7	12.2	9.9	8.4	6.1	4.6
78	29.6	30.4	24.2	17.2	12.5	10.1	8.6	6.2	4.7
80	30.4	31.2	24.8	17.6	12.8	10.4	8.8	6.4	4.8

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TABLE II.—*Weighted wind speeds for antiaircraft and other high-angle fire*—Con.

FOR ZONE 3,000–4,500 FEET

Speed	Point							
	43	53	63	73	83	93	03	13
2	0. 4	0. 5	0. 4	0. 3	0. 2	0. 2	0. 2	0. 1
4	. 8	1. 1	. 8	. 6	. 5	. 4	. 3	. 3
6	1. 2	1. 6	1. 2	. 9	. 7	. 6	. 5	. 4
8	1. 6	2. 2	1. 6	1. 2	1. 0	. 8	. 6	. 6
10	2. 0	2. 7	2. 0	1. 5	1. 2	1. 0	. 8	. 7
12	2. 4	3. 2	2. 4	1. 8	1. 4	1. 2	1. 0	. 8
14	2. 8	3. 8	2. 8	2. 1	1. 7	1. 4	1. 1	1. 0
16	3. 2	4. 3	3. 2	2. 4	1. 9	1. 6	1. 3	1. 1
18	3. 6	4. 9	3. 6	2. 7	2. 2	1. 8	1. 4	1. 3
20	4. 0	5. 4	4. 0	3. 0	2. 4	2. 0	1. 6	1. 4
22	4. 4	5. 9	4. 4	3. 3	2. 6	2. 2	1. 8	1. 5
24	4. 8	6. 5	4. 8	3. 6	2. 9	2. 4	1. 9	1. 7
26	5. 2	7. 0	5. 2	3. 9	3. 1	2. 6	2. 1	1. 8
28	5. 6	7. 6	5. 6	4. 2	3. 4	2. 8	2. 2	2. 0
30	6. 0	8. 1	6. 0	4. 5	3. 6	3. 0	2. 4	2. 1
32	6. 4	8. 6	6. 4	4. 8	3. 8	3. 2	2. 6	2. 2
34	6. 8	9. 2	6. 8	5. 1	4. 1	3. 4	2. 7	2. 4
36	7. 2	9. 7	7. 2	5. 4	4. 3	3. 6	2. 9	2. 5
38	7. 6	10. 3	7. 6	5. 7	4. 6	3. 8	3. 0	2. 7
40	8. 0	10. 8	8. 0	6. 0	4. 8	4. 0	3. 2	2. 8
42	8. 4	11. 3	8. 4	6. 3	5. 0	4. 2	3. 4	2. 9
44	8. 8	11. 9	8. 8	6. 6	5. 3	4. 4	3. 5	3. 1
46	9. 2	12. 4	9. 2	6. 9	5. 5	4. 6	3. 7	3. 2
48	9. 6	13. 0	9. 6	7. 2	5. 8	4. 8	3. 8	3. 4
50	10. 0	13. 5	10. 0	7. 5	6. 0	5. 0	4. 0	3. 5
52	10. 4	14. 0	10. 4	7. 8	6. 2	5. 2	4. 2	3. 6
54	10. 8	14. 6	10. 8	8. 1	6. 5	5. 4	4. 3	3. 8
56	11. 2	15. 1	11. 2	8. 4	6. 7	5. 6	4. 5	3. 9
58	11. 6	15. 7	11. 6	8. 7	7. 0	5. 8	4. 6	4. 1
60	12. 0	16. 2	12. 0	9. 0	7. 2	6. 0	4. 8	4. 2
62	12. 4	16. 7	12. 4	9. 3	7. 4	6. 2	5. 0	4. 3
64	12. 8	17. 3	12. 8	9. 6	7. 7	6. 4	5. 1	4. 5
66	13. 2	17. 8	13. 2	9. 9	7. 9	6. 6	5. 3	4. 6
68	13. 6	18. 4	13. 6	10. 2	8. 2	6. 8	5. 4	4. 8
70	14. 0	18. 9	14. 0	10. 5	8. 4	7. 0	5. 6	4. 9
72	14. 4	19. 4	14. 4	10. 8	8. 6	7. 2	5. 8	5. 0
74	14. 8	20. 0	14. 8	11. 1	8. 9	7. 4	5. 9	5. 2
76	15. 2	20. 5	15. 2	11. 4	9. 1	7. 6	6. 1	5. 3
78	15. 6	21. 1	15. 6	11. 7	9. 4	7. 8	6. 2	5. 5
80	16. 0	21. 6	16. 0	12. 0	9. 6	8. 0	6. 4	5. 6

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TABLE II.—*Weighted wind speeds for antiaircraft and other high-angle fire*—Con.

FOR ZONE 4,500–6,000 FEET

Speed	Point						
	54	64	74	84	94	04	14
2	0.2	0.4	0.3	0.3	0.2	0.2	0.1
4	.4	.8	.6	.5	.4	.3	.2
6	.7	1.1	1.0	.8	.6	.5	.4
8	.9	1.5	1.3	1.0	.8	.6	.5
10	1.1	1.9	1.6	1.3	1.0	.8	.6
12	1.3	2.3	1.9	1.6	1.2	1.0	.7
14	1.5	2.7	2.2	1.8	1.4	1.1	.8
16	1.8	3.0	2.6	2.1	1.6	1.3	1.0
18	2.0	3.4	2.9	2.3	1.8	1.4	1.1
20	2.2	3.8	3.2	2.6	2.0	1.6	1.2
22	2.4	4.2	3.5	2.9	2.2	1.8	1.3
24	2.6	4.6	3.8	3.1	2.4	1.9	1.4
26	2.9	4.9	4.2	3.4	2.6	2.1	1.6
28	3.1	5.3	4.5	3.6	2.8	2.2	1.7
30	3.3	5.7	4.8	3.9	3.0	2.4	1.8
32	3.5	6.1	5.1	4.2	3.2	2.6	1.9
34	3.7	6.5	5.4	4.4	3.4	2.7	2.0
36	4.0	6.8	5.8	4.7	3.6	2.9	2.2
38	4.2	7.2	6.1	4.9	3.8	3.0	2.3
40	4.4	7.6	6.4	5.2	4.0	3.2	2.4
42	4.6	8.0	6.7	5.5	4.2	3.4	2.5
44	4.8	8.4	7.0	5.7	4.4	3.5	2.6
46	5.1	8.7	7.4	6.0	4.6	3.7	2.8
48	5.3	9.1	7.7	6.2	4.8	3.8	2.9
50	5.5	9.5	8.0	6.5	5.0	4.0	3.0
52	5.7	9.9	8.3	6.8	5.2	4.2	3.1
54	5.9	10.3	8.6	7.0	5.4	4.3	3.2
56	6.2	10.6	9.0	7.3	5.6	4.5	3.4
58	6.4	11.0	9.3	7.5	5.8	4.6	3.5
60	6.6	11.4	9.6	7.8	6.0	4.8	3.6
62	6.8	11.8	9.9	8.1	6.2	5.0	3.7
64	7.0	12.2	10.2	8.3	6.4	5.1	3.8
66	7.3	12.5	10.6	8.6	6.6	5.3	4.0
68	7.5	12.9	10.9	8.8	6.8	5.4	4.1
70	7.7	13.3	11.2	9.1	7.0	5.6	4.2
72	7.9	13.7	11.5	9.4	7.2	5.8	4.3
74	8.1	14.1	11.8	9.6	7.4	5.9	4.4
76	8.4	14.4	12.2	9.9	7.6	6.1	4.6
78	8.6	14.8	12.5	10.1	7.8	6.2	4.7
80	8.8	15.2	12.8	10.4	8.0	6.4	4.8

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TABLE II.—*Weighted wind speeds for antiaircraft and other high-angle fire*—Con.

FOR ZONE 6,000–9,000 FEET

Speed	Point					
	65	75	85	95	05	15
2	0.4	0.5	0.5	0.4	0.3	0.3
4	.8	1.1	1.0	.8	.6	.5
6	1.1	1.6	1.4	1.3	1.0	.8
8	1.5	2.2	1.9	1.7	1.3	1.0
10	1.9	2.7	2.4	2.1	1.6	1.3
12	2.3	3.2	2.9	2.5	1.9	1.6
14	2.7	3.8	3.4	2.9	2.2	1.8
16	3.0	4.3	3.8	3.4	2.6	2.1
18	3.4	4.9	4.3	3.8	2.9	2.3
20	3.8	5.4	4.8	4.2	3.2	2.6
22	4.2	5.9	5.3	4.6	3.5	2.9
24	4.6	6.5	5.8	5.0	3.8	3.1
26	4.9	7.0	6.2	5.5	4.2	3.4
28	5.3	7.6	6.7	5.9	4.5	3.6
30	5.7	8.1	7.2	6.3	4.8	3.9
32	6.1	8.6	7.7	6.7	5.1	4.2
34	6.5	9.2	8.2	7.1	5.4	4.4
36	6.8	9.7	8.6	7.6	5.8	4.7
38	7.2	10.3	9.1	8.0	6.1	4.9
40	7.6	10.8	9.6	8.4	6.4	5.2
42	8.0	11.3	10.1	8.8	6.7	5.5
44	8.4	11.9	10.6	9.2	7.0	5.7
46	8.7	12.4	11.0	9.7	7.4	6.0
48	9.1	13.0	11.5	10.1	7.7	6.2
50	9.5	13.5	12.0	10.5	8.0	6.5
52	9.9	14.0	12.5	10.9	8.3	6.8
54	10.3	14.6	13.0	11.3	8.6	7.0
56	10.6	15.1	13.4	11.8	9.0	7.3
58	11.0	15.7	13.9	12.2	9.3	7.5
60	11.4	16.2	14.4	12.6	9.6	7.8
62	11.8	16.7	14.9	13.0	9.9	8.1
64	12.2	17.3	15.4	13.4	10.2	8.3
66	12.5	17.8	15.8	13.9	10.6	8.6
68	12.9	18.4	16.3	14.3	10.9	8.8
70	13.3	18.9	16.8	14.7	11.2	9.1
72	13.7	19.4	17.3	15.1	11.5	9.4
74	14.1	20.0	17.8	15.5	11.8	9.6
76	14.4	20.5	18.2	16.0	12.2	9.9
78	14.8	21.1	18.7	16.4	12.5	10.1
80	15.2	21.6	19.2	16.8	12.8	10.4

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TABLE II.—*Weighted wind speeds for antiaircraft and other high-angle fire*—Con.

FOR ZONE 9,000–12,000 FEET

Speed	Point				
	76	86	96	06	16
2	0.2	0.4	0.4	0.3	0.3
4	.4	.7	.8	.6	.5
6	.7	1.1	1.2	.9	.8
8	.9	1.4	1.6	1.2	1.0
10	1.1	1.8	2.0	1.5	1.3
12	1.3	2.2	2.4	1.8	1.6
14	1.5	2.5	2.8	2.1	1.8
16	1.8	2.9	3.2	2.4	2.1
18	2.0	3.2	3.6	2.7	2.3
20	2.2	3.6	4.0	3.0	2.6
22	2.4	4.0	4.4	3.3	2.9
24	2.6	4.3	4.8	3.6	3.1
26	2.9	4.7	5.2	3.9	3.4
28	3.1	5.0	5.6	4.2	3.6
30	3.3	5.4	6.0	4.5	3.9
32	3.5	5.8	6.4	4.8	4.2
34	3.7	6.1	6.8	5.1	4.4
36	4.0	6.5	7.2	5.4	4.7
38	4.2	6.8	7.6	5.7	4.9
40	4.4	7.2	8.0	6.0	5.2
42	4.6	7.6	8.4	6.3	5.5
44	4.8	7.9	8.8	6.6	5.7
46	5.1	8.3	9.2	6.9	6.0
48	5.3	8.6	9.6	7.2	6.2
50	5.5	9.0	10.0	7.5	6.5
52	5.7	9.4	10.4	7.8	6.8
54	5.9	9.7	10.8	8.1	7.0
56	6.2	10.1	11.2	8.4	7.3
58	6.4	10.4	11.6	8.7	7.5
60	6.6	10.8	12.0	9.0	7.8
62	6.8	11.2	12.4	9.3	8.1
64	7.0	11.5	12.8	9.6	8.3
66	7.3	11.9	13.2	9.9	8.6
68	7.5	12.2	13.6	10.2	8.8
70	7.7	12.6	14.0	10.5	9.1
72	7.9	13.0	14.4	10.8	9.4
74	8.1	13.3	14.8	11.1	9.6
76	8.4	13.7	15.2	11.4	9.9
78	8.6	14.0	15.6	11.7	10.1
80	8.8	14.4	16.0	12.0	10.4

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TABLE II.—*Weighted wind speeds for antiaircraft and other high-angle fire*—Con.

FOR ZONE 12,000–15,000 FEET					FOR ZONE 15,000–18,000 FEET			
Speed	Point				Speed	Point		
	87	97	07	17		98	08	18
2	0.2	0.2	0.3	0.2	2	0.1	0.3	0.2
4	.3	.5	.6	.5	4	.2	.5	.4
6	.5	.7	.8	.7	6	.4	.8	.7
8	.6	1.0	1.1	1.0	8	.5	1.0	.9
10	.8	1.2	1.4	1.2	10	.6	1.3	1.1
12	1.0	1.4	1.7	1.4	12	.7	1.6	1.3
14	1.1	1.7	2.0	1.7	14	.8	1.8	1.5
16	1.3	1.9	2.2	1.9	16	1.0	2.1	1.8
18	1.4	2.2	2.5	2.2	18	1.1	2.3	2.0
20	1.6	2.4	2.8	2.4	20	1.2	2.6	2.2
22	1.8	2.6	3.1	2.6	22	1.3	2.9	2.4
24	1.9	2.9	3.4	2.9	24	1.4	3.1	2.6
26	2.1	3.1	3.6	3.1	26	1.6	3.4	2.9
28	2.2	3.4	3.9	3.4	28	1.7	3.6	3.1
30	2.4	3.6	4.2	3.6	30	1.8	3.9	3.3
32	2.6	3.8	4.5	3.8	32	1.9	4.2	3.5
34	2.7	4.1	4.8	4.1	34	2.0	4.4	3.7
36	2.9	4.3	5.0	4.3	36	2.2	4.7	4.0
38	3.0	4.6	5.3	4.6	38	2.3	4.9	4.2
40	3.2	4.8	5.6	4.8	40	2.4	5.2	4.4
42	3.4	5.0	5.9	5.0	42	2.5	5.5	4.6
44	3.5	5.3	6.2	5.3	44	2.6	5.7	4.8
46	3.7	5.5	6.4	5.5	46	2.8	6.0	5.1
48	3.8	5.8	6.7	5.8	48	2.9	6.2	5.3
50	4.0	6.0	7.0	6.0	50	3.0	6.5	5.5
52	4.2	6.2	7.3	6.2	52	3.1	6.8	5.7
54	4.3	6.5	7.6	6.5	54	3.2	7.0	5.9
56	4.5	6.7	7.8	6.7	56	3.4	7.3	6.2
58	4.6	7.0	8.1	7.0	58	3.5	7.5	6.4
60	4.8	7.2	8.4	7.2	60	3.6	7.8	6.6
62	5.0	7.4	8.7	7.4	62	3.7	8.1	6.8
64	5.1	7.7	9.0	7.7	64	3.8	8.3	7.0
66	5.3	7.9	9.2	7.9	66	4.0	8.6	7.3
68	5.4	8.2	9.5	8.2	68	4.1	8.8	7.5
70	5.6	8.4	9.8	8.4	70	4.2	9.1	7.7
72	5.8	8.6	10.1	8.6	72	4.3	9.4	7.9
74	5.9	8.9	10.4	8.9	74	4.4	9.6	8.1
76	6.1	9.1	10.6	9.1	76	4.6	9.9	8.4
78	6.2	9.4	10.9	9.4	78	4.7	10.1	8.6
80	6.4	9.6	11.2	9.6	80	4.8	10.4	8.8

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TABLE II.—*Weighted wind speeds for antiaircraft and other high-angle fire*—Con.

FOR ZONE 18,000–24,000 FEET			FOR ZONE 24,000–30,000 FEET	
Speed	Point		Speed	Point
	09	19		10
2	0. 2	0. 4	2	0. 2
4	. 4	. 7	4	. 3
6	. 7	1. 1	6	. 5
8	. 9	1. 4	8	. 6
10	1. 1	1. 8	10	. 8
12	1. 3	2. 2	12	1. 0
14	1. 5	2. 5	14	1. 1
16	1. 8	2. 9	16	1. 3
18	2. 0	3. 2	18	1. 4
20	2. 2	3. 6	20	1. 6
22	2. 4	4. 0	22	1. 8
24	2. 6	4. 3	24	1. 9
26	2. 9	4. 7	26	2. 1
28	3. 1	5. 0	28	2. 2
30	3. 3	5. 4	30	2. 4
32	3. 5	5. 8	32	2. 6
34	3. 7	6. 1	34	2. 7
36	4. 0	6. 5	36	2. 9
38	4. 2	6. 8	38	3. 0
40	4. 4	7. 2	40	3. 2
42	4. 6	7. 6	42	3. 4
44	4. 8	7. 9	44	3. 5
46	5. 1	8. 3	46	3. 7
48	5. 3	8. 6	48	3. 8
50	5. 5	9. 0	50	4. 0
52	5. 7	9. 4	52	4. 2
54	5. 9	9. 7	54	4. 3
56	6. 2	10. 1	56	4. 5
58	6. 4	10. 4	58	4. 6
60	6. 6	10. 8	60	4. 8
62	6. 8	11. 2	62	5. 0
64	7. 0	11. 5	64	5. 1
66	7. 3	11. 9	66	5. 3
68	7. 5	12. 2	68	5. 4
70	7. 7	12. 6	70	5. 6
72	7. 9	13. 0	72	5. 8
74	8. 1	13. 3	74	5. 9
76	8. 4	13. 7	76	6. 1
78	8. 6	14. 0	78	6. 2
80	8. 8	14. 4	80	6. 4

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TABLE III.—*Wind weighting factors for low-angle fire*

Standard altitude (feet)	Zones									
	0 to 1,500	1,500 to 3,000	3,000 to 4,000	4,500 to 6,000	6,000 to 9,000	9,000 to 12,000	12,000 to 15,000	15,000 to 18,000	18,000 to 24,000	24,000 to 30,000
600 [1]	------	------	------	------	------	------	------	------	------	------
1,500 [2]	------	------	------	------	------	------	------	------	------	------
3,000	0. 41	0. 59	------	------	------	------	------	------	------	------
4,500	. 28	. 26	0. 46	------	------	------	------	------	------	------
6,000	. 21	. 20	. 20	0. 39	------	------	------	------	------	------
9,000	. 14	. 14	. 13	. 13	0. 46	------	------	------	------	------
12,000	. 11	. 10	. 10	. 10	. 20	0. 39	------	------	------	------
15,000	. 09	. 08	. 08	. 08	. 16	. 16	0. 35	------	------	------
18,000	. 07	. 07	. 07	. 07	. 13	. 13	. 14	0. 32	------	------
24,000	. 06	. 05	. 05	. 05	. 10	. 10	. 10	. 10	0. 39	------
30,000	. 05	. 04	. 04	. 04	. 08	. 08	. 08	. 08	. 16	0. 35

[1] Use wind during first minute of balloon ascension.

[2] Use wind during first 2¼ minutes of balloon ascension.

NOTE.—The above wind weighting factors were furnished by the Ordnance Department. These wind weighting factors are used in the preparation of table IV. Table IV is used in preparing "message 3."

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INSTRUCTIONS FOR USING TABLE IV

Table IV is used by the assistant at plotting board ML–120 and ML–57 in determining ballistic winds for "message 3." The use of table IV eliminates the necessity of multiplying the speed of the zone winds by the weighting factors in table III.

The instructions for the use of table IV are the same as the instructions for the use of table II.

TABLE IV.—*Weighted wind speeds for low-angle fire.*
FOR ZONE 0–1,500 FEET

Speed	Point								
	31	41	51	61	71	81	91	01	11
2	0. 8	0. 6	0. 4	0. 3	0. 2	0. 2	0. 1	0. 1	0. 1
4	1. 6	1. 1	. 8	. 6	. 4	. 4	. 3	. 2	. 2
6	2. 5	1. 7	1. 3	. 8	. 7	. 5	. 4	. 4	. 3
8	3. 3	2. 2	1. 7	1. 1	. 9	. 7	. 6	. 5	. 4
10	4. 1	2. 8	2. 1	1. 4	1. 1	. 9	. 7	. 6	. 5
12	4. 9	3. 4	2. 5	1. 7	1. 3	1. 1	. 8	. 7	. 6
14	5. 7	3. 9	2. 9	2. 0	1. 5	1. 3	1. 0	. 8	. 7
16	6. 6	4. 5	3. 4	2. 2	1. 8	1. 4	1. 1	1. 0	. 8
18	7. 4	5. 0	3. 8	2. 5	2. 0	1. 6	1. 3	1. 1	. 9
20	8. 2	5. 6	4. 2	2. 8	2. 2	1. 8	1. 4	1. 2	1. 0
22	9. 0	6. 2	4. 6	3. 1	2. 4	2. 0	1. 5	1. 3	1. 1
24	9. 8	6. 7	5. 0	3. 4	2. 6	2. 2	1. 7	1. 4	1. 2
26	10. 7	7. 3	5. 5	3. 6	2. 9	2. 3	1. 8	1. 6	1. 3
28	11. 5	7. 8	5. 9	3. 9	3. 1	2. 5	2. 0	1. 7	1. 4
30	12. 3	8. 4	6. 3	4. 2	3. 3	2. 7	2. 1	1. 8	1. 5
32	13. 1	9. 0	6. 7	4. 5	3. 5	2. 9	2. 2	1. 9	1. 6
34	13. 9	9. 5	7. 1	4. 8	3. 7	3. 1	2. 4	2. 0	1. 7
36	14. 8	10. 1	7. 6	5. 0	4. 0	3. 2	2. 5	2. 2	1. 8
38	15. 6	10. 6	8. 0	5. 3	4. 2	3. 4	2. 7	2. 3	1. 9
40	16. 4	11. 2	8. 4	5. 6	4. 4	3. 6	2. 8	2. 4	2. 0
42	17. 2	11. 8	8. 8	5. 9	4. 6	3. 8	2. 9	2. 5	2. 1
44	18. 0	12. 3	9. 2	6. 2	4. 8	4. 0	3. 1	2. 6	2. 2
46	18. 9	12. 9	9. 7	6. 4	5. 1	4. 1	3. 2	2. 8	2. 3
48	19. 7	13. 4	10. 1	6. 7	5. 3	4. 3	3. 4	2. 9	2. 4
50	20. 5	14. 0	10. 5	7. 0	5. 5	4. 5	3. 5	3. 0	2. 5
52	21. 3	14. 6	10. 9	7. 3	5. 7	4. 7	3. 6	3. 1	2. 6
54	22. 1	15. 1	11. 3	7. 6	5. 9	4. 9	3. 8	3. 2	2. 7
56	23. 0	15. 7	11. 8	7. 8	6. 2	5. 0	3. 9	3. 4	2. 8
58	23. 8	16. 2	12. 2	8. 1	6. 4	5. 2	4. 1	3. 5	2. 9
60	24. 6	16. 8	12. 6	8. 4	6. 6	5. 4	4. 2	3. 6	3. 0
62	25. 4	17. 4	13. 0	8. 7	6. 8	5. 6	4. 3	3. 7	3. 1
64	26. 2	17. 9	13. 4	9. 0	7. 0	5. 8	4. 5	3. 8	3. 2
66	27. 1	18. 5	13. 9	9. 2	7. 3	5. 9	4. 6	4. 0	3. 3
68	27. 9	19. 0	14. 3	9. 5	7. 5	6. 1	4. 8	4. 1	3. 4
70	28. 7	19. 6	14. 7	9. 8	7. 7	6. 3	4. 9	4. 2	3. 5
72	29. 5	20. 2	15. 1	10. 1	7. 9	6. 5	5. 0	4. 3	3. 6
74	30. 3	20. 7	15. 5	10. 4	8. 1	6. 7	5. 2	4. 4	3. 7
76	31. 2	21. 3	16. 0	10. 6	8. 4	6. 8	5. 3	4. 6	3. 8
78	32. 0	21. 8	16. 4	10. 9	8. 6	7. 0	5. 5	4. 7	3. 9
80	32. 8	22. 4	16. 8	11. 2	8. 8	7. 2	5. 6	4. 8	4. 0

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TABLE IV.—*Weighted wind speeds for low-angle fire*—Continued

FOR ZONE 1,500–3,000 FEET

Speed	Point								
	32	42	52	62	72	82	92	02	12
2	1. 2	0. 5	0. 4	0. 3	0. 2	0. 2	0. 1	0. 1	0. 1
4	2. 4	1. 0	. 8	. 6	. 4	. 3	. 3	. 2	. 2
6	3. 5	1. 6	1. 2	. 8	. 6	. 5	. 4	. 3	. 2
8	4. 7	2. 1	1. 6	1. 1	. 8	. 6	. 6	. 4	. 3
10	5. 9	2. 6	2. 0	1. 4	1. 0	. 8	. 7	. 5	. 4
12	7. 1	3. 1	2. 4	1. 7	1. 2	1. 0	. 8	. 6	. 5
14	8. 3	3. 6	2. 8	2. 0	1. 4	1. 1	1. 0	. 7	. 6
16	9. 4	4. 2	3. 2	2. 2	1. 6	1. 3	1. 1	. 8	. 6
18	10. 6	4. 7	3. 6	2. 5	1. 8	1. 4	1. 3	. 9	. 7
20	11. 8	5. 2	4. 0	2. 8	2. 0	1. 6	1. 4	1. 0	. 8
22	13. 0	5. 7	4. 4	3. 1	2. 2	1. 8	1. 5	1. 1	. 9
24	14. 2	6. 2	4. 8	3. 4	2. 4	1. 9	1. 7	1. 2	1. 0
26	15. 3	6. 8	5. 2	3. 6	2. 6	2. 1	1. 8	1. 3	1. 0
28	16. 5	7. 3	5. 6	3. 9	2. 8	2. 2	2. 0	1. 4	1. 1
30	17. 7	7. 8	6. 0	4. 2	3. 0	2. 4	2. 1	1. 5	1. 2
32	18. 9	8. 3	6. 4	4. 5	3. 2	2. 6	2. 2	1. 6	1. 3
34	20. 1	8. 8	6. 8	4. 8	3. 4	2. 7	2. 4	1. 7	1. 4
36	21. 2	9. 4	7. 2	5. 0	3. 6	2. 9	2. 5	1. 8	1. 4
38	22. 4	9. 9	7. 6	5. 3	3. 8	3. 0	2. 7	1. 9	1. 5
40	23. 6	10. 4	8. 0	5. 6	4. 0	3. 2	2. 8	2. 0	1. 6
42	24. 8	10. 9	8. 4	5. 9	4. 2	3. 4	2. 9	2. 1	1. 7
44	26. 0	11. 4	8. 8	6. 2	4. 4	3. 5	3. 1	2. 2	1. 8
46	27. 1	12. 0	9. 2	6. 4	4. 6	3. 7	3. 2	2. 3	1. 8
48	28. 3	12. 5	9. 6	6. 7	4. 8	3. 8	3. 4	2. 4	1. 9
50	29. 5	13. 0	10. 0	7. 0	5. 0	4. 0	3. 5	2. 5	2. 0
52	30. 7	13. 5	10. 4	7. 3	5. 2	4. 2	3. 6	2. 6	2. 1
54	31. 9	14. 0	10. 8	7. 6	5. 4	4. 3	3. 8	2. 7	2. 2
56	33. 0	14. 6	11. 2	7. 8	5. 6	4. 5	3. 9	2. 8	2. 2
58	34. 2	15. 1	11. 6	8. 1	5. 8	4. 6	4. 1	2. 9	2. 3
60	35. 4	15. 6	12. 0	8. 4	6. 0	4. 8	4. 2	3. 0	2. 4
62	36. 6	16. 1	12. 4	8. 7	6. 2	5. 0	4. 3	3. 1	2. 5
64	37. 8	16. 6	12. 8	9. 0	6. 4	5. 1	4. 5	3. 2	2. 6
66	38. 9	17. 2	13. 2	9. 2	6. 6	5. 3	4. 6	3. 3	2. 6
68	40. 1	17. 7	13. 6	9. 5	6. 8	5. 4	4. 8	3. 4	2. 7
70	41. 3	18. 2	14. 0	9. 8	7. 0	5. 6	4. 9	3. 5	2. 8
72	42. 5	18. 7	14. 4	10. 1	7. 2	5. 8	5. 0	3. 6	2. 9
74	43. 7	19. 2	14. 8	10. 4	7. 4	5. 9	5. 2	3. 7	3. 0
76	44. 8	19. 8	15. 2	10. 6	7. 6	6. 1	5. 3	3. 8	3. 0
78	46. 0	20. 3	15. 6	10. 9	7. 8	6. 2	5. 5	3. 9	3. 1
80	47. 2	20. 8	16. 0	11. 2	8. 0	6. 4	5. 6	4. 0	3. 2

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TABLE IV.—*Weighted wind speeds for low-angle fire*—Continued

FOR ZONE 3,000-4,500 FEET

Speed	Point							
	43	53	63	73	83	93	03	13
2	0.9	0.4	0.3	0.2	0.2	0.1	0.1	0.1
4	1.8	.8	.5	.4	.3	.3	.2	.2
6	2.8	1.2	.8	.6	.5	.4	.3	.2
8	3.7	1.6	1.0	.8	.6	.6	.4	.3
10	4.6	2.0	1.3	1.0	.8	.7	.5	.4
12	5.5	2.4	1.6	1.2	1.0	.8	.6	.5
14	6.4	2.8	1.8	1.4	1.1	1.0	.7	.6
16	7.4	3.2	2.1	1.6	1.3	1.1	.8	.6
18	8.3	3.6	2.3	1.8	1.4	1.3	.9	.7
20	9.2	4.0	2.6	2.0	1.6	1.4	1.0	.8
22	10.1	4.4	2.9	2.2	1.8	1.5	1.1	.9
24	11.0	4.8	3.1	2.4	1.9	1.7	1.2	1.0
26	12.0	5.2	3.4	2.6	2.1	1.8	1.3	1.0
28	12.9	5.6	3.6	2.8	2.2	2.0	1.4	1.1
30	13.8	6.0	3.9	3.0	2.4	2.1	1.5	1.2
32	14.7	6.4	4.2	3.2	2.6	2.2	1.6	1.3
34	15.6	6.8	4.4	3.4	2.7	2.4	1.7	1.4
36	16.6	7.2	4.7	3.6	2.9	2.5	1.8	1.4
38	17.5	7.6	4.9	3.8	3.0	2.7	1.9	1.5
40	18.4	8.0	5.2	4.0	3.2	2.8	2.0	1.6
42	19.3	8.4	5.5	4.2	3.4	2.9	2.1	1.7
44	20.2	8.8	5.7	4.4	3.5	3.1	2.2	1.8
46	21.2	9.2	6.0	4.6	3.7	3.2	2.3	1.8
48	22.1	9.6	6.2	4.8	3.8	3.4	2.4	1.9
50	23.0	10.0	6.5	5.0	4.0	3.5	2.5	2.0
52	23.9	10.4	6.8	5.2	4.2	3.6	2.6	2.1
54	24.8	10.8	7.0	5.4	4.3	3.8	2.7	2.2
56	25.8	11.2	7.3	5.6	4.5	3.9	2.8	2.2
58	26.7	11.6	7.5	5.8	4.6	4.1	2.9	2.3
60	27.6	12.0	7.8	6.0	4.8	4.2	3.0	2.4
62	28.5	12.4	8.1	6.2	5.0	4.3	3.1	2.5
64	29.4	12.8	8.3	6.4	5.1	4.5	3.2	2.6
66	30.4	13.2	8.6	6.6	5.3	4.6	3.3	2.6
68	31.3	13.6	8.8	6.8	5.4	4.8	3.4	2.7
70	32.2	14.0	9.1	7.0	5.6	4.9	3.5	2.8
72	33.1	14.4	9.4	7.2	5.8	5.0	3.6	2.9
74	34.0	14.8	9.6	7.4	5.9	5.2	3.7	3.0
76	35.0	15.2	9.9	7.6	6.1	5.3	3.8	3.0
78	35.9	15.6	10.1	7.8	6.2	5.5	3.9	3.1
80	36.8	16.0	10.4	8.0	6.4	5.6	4.0	3.2

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TABLE IV.—*Weighted wind speeds for low-angle fire*—Continued

FOR 4,500–6,000 FEET

Speed	Point						
	54	64	74	84	94	04	14
2	0. 8	0. 3	0. 2	0. 2	0. 1	0. 1	0. 1
4	1. 6	. 5	. 4	. 3	. 3	. 2	. 2
6	2. 3	. 8	. 6	. 5	. 4	. 3	. 2
8	3. 1	1. 0	. 8	. 6	. 6	. 4	. 3
10	3. 9	1. 3	1. 0	. 8	. 7	. 5	. 4
12	4. 7	1. 6	1. 2	1. 0	. 8	. 6	. 5
14	5. 5	1. 8	1. 4	1. 1	1. 0	. 7	. 6
16	6. 2	2. 1	1. 6	1. 3	1. 1	. 8	. 6
18	7. 0	2. 3	1. 8	1. 4	1. 3	. 9	. 7
20	7. 8	2. 6	2. 0	1. 6	1. 4	1. 0	. 8
22	8. 6	2. 9	2. 2	1. 8	1. 5	1. 1	. 9
24	9. 4	3. 1	2. 4	1. 9	1. 7	1. 2	1. 0
26	10. 1	3. 4	2. 6	2. 1	1. 8	1. 3	1. 0
28	10. 9	3. 6	2. 8	2. 2	2. 0	1. 4	1. 1
30	11. 7	3. 9	3. 0	2. 4	2. 1	1. 5	1. 2
32	12. 5	4. 2	3. 2	2. 6	2. 2	1. 6	1. 3
34	13. 3	4. 4	3. 4	2. 7	2. 4	1. 7	1. 4
36	14. 0	4. 7	3. 6	2. 9	2. 5	1. 8	1. 4
38	14. 8	4. 9	3. 8	3. 0	2. 7	1. 9	1. 5
40	15. 6	5. 2	4. 0	3. 2	2. 8	2. 0	1. 6
42	16. 4	5. 5	4. 2	3. 4	2. 9	2. 1	1. 7
44	17. 2	5. 7	4. 4	3. 5	3. 1	2. 2	1. 8
46	17. 9	6. 0	4. 6	3. 7	3. 2	2. 3	1. 8
48	18. 7	6. 2	4. 8	3. 8	3. 4	2. 4	1. 9
50	19. 5	6. 5	5. 0	4. 0	3. 5	2. 5	2. 0
52	20. 3	6. 8	5. 2	4. 2	3. 6	2. 6	2. 1
54	21. 1	7. 0	5. 4	4. 3	3. 8	2. 7	2. 2
56	21. 8	7. 3	5. 6	4. 5	3. 9	2. 8	2. 2
58	22. 6	7. 5	5. 8	4. 6	4. 1	2. 9	2. 3
60	23. 4	7. 8	6. 0	4. 8	4. 2	3. 0	2. 4
62	24. 2	8. 1	6. 2	5. 0	4. 3	3. 1	2. 5
64	25. 0	8. 3	6. 4	5. 1	4. 5	3. 2	2. 6
66	25. 7	8. 6	6. 6	5. 3	4. 6	3. 3	2. 6
68	26. 5	8. 8	6. 8	5. 4	4. 8	3. 4	2. 7
70	27. 3	9. 1	7. 0	5. 6	4. 9	3. 5	2. 8
72	28. 1	9. 4	7. 2	5. 8	5. 0	3. 6	2. 9
74	28. 9	9. 6	7. 4	5. 9	5. 2	3. 7	3. 0
76	29. 6	9. 9	7. 6	6. 1	5. 3	3. 8	3. 0
78	30. 4	10. 1	7. 8	6. 2	5. 5	3. 9	3. 1
80	31. 2	10. 4	8. 0	6. 4	5. 6	4. 0	3. 2

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TABLE IV.—*Weighted wind speeds for low-angle fire*—Continued

FOR ZONE 6,000–9,000 FEET

Speed	Point					
	65	75	85	95	05	15
2	0. 9	0. 4	0. 3	0. 3	0. 2	0. 2
4	1. 8	. 8	. 6	. 5	. 4	. 3
6	2. 8	1. 2	1. 0	. 8	. 6	. 5
8	3. 7	1. 6	1. 3	1. 0	. 8	. 6
10	4. 6	2. 0	1. 6	1. 3	1. 0	. 8
12	5. 5	2. 4	1. 9	1. 6	1. 2	1. 0
14	6. 4	2. 8	2. 2	1. 8	1. 4	1. 1
16	7. 4	3. 2	2. 6	2. 1	1. 6	1. 3
18	8. 3	3. 6	2. 9	2. 3	1. 8	1. 4
20	9. 2	4. 0	3. 2	2. 6	2. 0	1. 6
22	10. 1	4. 4	3. 5	2. 9	2. 2	1. 8
24	11. 0	4. 8	3. 8	3. 1	2. 4	1. 9
26	12. 0	5. 2	4. 2	3. 4	2. 6	2. 1
28	12. 9	5. 6	4. 5	3. 6	2. 8	2. 2
30	13. 8	6. 0	4. 8	3. 9	3. 0	2. 4
32	14. 7	6. 4	5. 1	4. 2	3. 2	2. 6
34	15. 6	6. 8	5. 4	4. 4	3. 4	2. 7
36	16. 6	7. 2	5. 8	4. 7	3. 6	2. 9
38	17. 5	7. 6	6. 1	4. 9	3. 8	3. 0
40	18. 4	8. 0	6. 4	5. 2	4. 0	3. 2
42	19. 3	8. 4	6. 7	5. 5	4. 2	3. 4
44	20. 2	8. 8	7. 0	5. 7	4. 4	3. 5
46	21. 2	9. 2	7. 4	6. 0	4. 6	3. 7
48	22. 1	9. 6	7. 7	6. 2	4. 8	3. 8
50	23. 0	10. 0	8. 0	6. 5	5. 0	4. 0
52	23. 9	10. 4	8. 3	6. 8	5. 2	4. 2
54	24. 8	10. 8	8. 6	7. 0	5. 4	4. 3
56	25. 8	11. 2	9. 0	7. 3	5. 6	4. 5
58	26. 7	11. 6	9. 3	7. 5	5. 8	4. 6
60	27. 6	12. 0	9. 6	7. 8	6. 0	4. 8
62	28. 5	12. 4	9. 9	8. 1	6. 2	5. 0
64	29. 4	12. 8	10. 2	8. 3	6. 4	5. 1
66	30. 4	13. 2	10. 6	8. 6	6. 6	5. 3
68	31. 3	13. 6	10. 9	8. 8	6. 8	5. 4
70	32. 2	14. 0	11. 2	9. 1	7. 0	5. 6
72	33. 1	14. 4	11. 5	9. 4	7. 2	5. 8
74	34. 0	14. 8	11. 8	9. 6	7. 4	5. 9
76	35. 0	15. 2	12. 2	9. 9	7. 6	6. 1
78	35. 9	15. 6	12. 5	10. 1	7. 8	6. 2
80	36. 8	16. 0	12. 8	10. 4	8. 0	6. 4

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TABLE IV.—*Weighted wind speeds for low-angle fire*—Continued

FOR ZONE 9,000–12,000 FEET

Speed	Point				
	76	86	96	06	16
2	0. 8	0. 3	0. 3	0. 2	0. 2
4	1. 6	. 6	. 5	. 4	. 3
6	2. 3	1. 0	. 8	. 6	. 5
8	3. 1	1. 3	1. 0	. 8	. 6
10	3. 9	1. 6	1. 3	1. 0	. 8
12	4. 7	1. 9	1. 6	1. 2	1. 0
14	5. 5	2. 2	1. 8	1. 4	1. 1
16	6. 2	2. 6	2. 1	1. 6	1. 3
18	7. 0	2. 9	2. 3	1. 8	1. 4
20	7. 8	3. 2	2. 6	2. 0	1. 6
22	8. 6	3. 5	2. 9	2. 2	1. 8
24	9. 4	3. 8	3. 1	2. 4	1. 9
26	10. 1	4. 2	3. 4	2. 6	2. 1
28	10. 9	4. 5	3. 6	2. 8	2. 2
30	11. 7	4. 8	3. 9	3. 0	2. 4
32	12. 5	5. 1	4. 2	3. 2	2. 6
34	13. 3	5. 4	4. 4	3. 4	2. 7
36	14. 0	5. 8	4. 7	3. 6	2. 9
38	14. 8	6. 1	4. 9	3. 8	3. 0
40	15. 6	6. 4	5. 2	4. 0	3. 2
42	16. 4	6. 7	5. 5	4. 2	3. 4
44	17. 2	7. 0	5. 7	4. 4	3. 5
46	17. 9	7. 4	6. 0	4. 6	3. 7
48	18. 7	7. 7	6. 2	4. 8	3. 8
50	19. 5	8. 0	6. 5	5. 0	4. 0
52	20. 3	8. 3	6. 8	5. 2	4. 2
54	21. 1	8. 6	7. 0	5. 4	4. 3
56	21. 8	9. 0	7. 3	5. 6	4. 5
58	22. 6	9. 3	7. 5	5. 8	4. 6
60	23. 4	9. 6	7. 8	6. 0	4. 8
62	24. 2	9. 9	8. 1	6. 2	5. 0
64	25. 0	10. 2	8. 3	6. 4	5. 1
66	25. 7	10. 6	8. 6	6. 6	5. 3
68	26. 5	10. 9	8. 8	6. 8	5. 4
70	27. 3	11. 2	9. 1	7. 0	5. 6
72	28. 1	11. 5	9. 4	7. 2	5. 8
74	28. 9	11. 8	9. 6	7. 4	5. 9
76	29. 6	12. 2	9. 9	7. 6	6. 1
78	30. 4	12. 5	10. 1	7. 8	6. 2
80	31. 2	12. 8	10. 4	8. 0	6. 4

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TABLE IV.—*Weighted wind speeds for low-angle fire*—Continued

FOR ZONE 12,000–15,000 FEET					FOR ZONE 15,000–18,000 FEET			
Speed	Point				Speed	Point		
	87	97	07	17		98	08	18
2	0.7	0.3	0.2	0.2	2	0.6	0.2	0.2
4	1.4	.6	.4	.3	4	1.3	.4	.3
6	2.1	.8	.6	.5	6	1.9	.6	.5
8	2.8	1.1	.8	.6	8	2.6	.8	.6
10	3.5	1.4	1.0	.8	10	3.2	1.0	.8
12	4.2	1.7	1.2	1.0	12	3.8	1.2	1.0
14	4.9	2.0	1.4	1.1	14	4.5	1.4	1.1
16	5.6	2.2	1.6	1.3	16	5.1	1.6	1.3
18	6.3	2.5	1.8	1.4	18	5.8	1.8	1.4
20	7.0	2.8	2.0	1.6	20	6.4	2.0	1.6
22	7.7	3.1	2.2	1.8	22	7.0	2.2	1.8
24	8.4	3.4	2.4	1.9	24	7.7	2.4	1.9
26	9.1	3.6	2.6	2.1	26	8.3	2.6	2.1
28	9.8	3.9	2.8	2.2	28	9.0	2.8	2.2
30	10.5	4.2	3.0	2.4	30	9.6	3.0	2.4
32	11.2	4.5	3.2	2.6	32	10.2	3.2	2.6
34	11.9	4.8	3.4	2.7	34	10.9	3.4	2.7
36	12.6	5.0	3.6	2.9	36	11.5	3.6	2.9
38	13.3	5.3	3.8	3.0	38	12.2	3.8	3.0
40	14.0	5.6	4.0	3.2	40	12.8	4.0	3.2
42	14.7	5.9	4.2	3.4	42	13.4	4.2	3.4
44	15.4	6.2	4.4	3.5	44	14.1	4.4	3.5
46	16.1	6.4	4.6	3.7	46	14.7	4.6	3.7
48	16.8	6.7	4.8	3.8	48	15.4	4.8	3.8
50	17.5	7.0	5.0	4.0	50	16.0	5.0	4.0
52	18.2	7.3	5.2	4.2	52	16.6	5.2	4.2
54	18.9	7.6	5.4	4.3	54	17.3	5.4	4.3
56	19.6	7.8	5.6	4.5	56	17.9	5.6	4.5
58	20.3	8.1	5.8	4.6	58	18.6	5.8	4.6
60	21.0	8.4	6.0	4.8	60	19.2	6.0	4.8
62	21.7	8.7	6.2	5.0	62	19.8	6.2	5.0
64	22.4	9.0	6.4	5.1	64	20.5	6.4	5.1
66	23.1	9.2	6.6	5.3	66	21.1	6.6	5.3
68	23.8	9.5	6.8	5.4	68	21.8	6.8	5.4
70	24.5	9.8	7.0	5.6	70	22.4	7.0	5.6
72	25.2	10.1	7.2	5.8	72	23.0	7.2	5.8
74	25.9	10.4	7.4	5.9	74	23.7	7.4	5.9
76	26.6	10.6	7.6	6.1	76	24.3	7.6	6.1
78	27.3	10.9	7.8	6.2	78	25.0	7.8	6.2
80	28.0	11.2	8.0	6.4	80	25.6	8.0	6.4

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TABLE IV.—*Weighted wind speeds for low-angle fire*—Continued

FOR ZONE 18,000–24,000 FEET			FOR ZONE 24,000–30,000 FEET	
Speed	Point		Speed	Point
	09	19		10
2	0.8	0.3	2	0.7
4	1.6	.6	4	1.4
6	2.3	1.0	6	2.1
8	3.1	1.3	8	2.8
10	3.9	1.6	10	3.5
12	4.7	1.9	12	4.2
14	5.5	2.2	14	4.9
16	6.2	2.6	16	5.6
18	7.0	2.9	18	6.3
20	7.8	3.2	20	7.0
22	8.6	3.5	22	7.7
24	9.4	3.8	24	8.4
26	10.1	4.2	26	9.1
28	10.9	4.5	28	9.8
30	11.7	4.8	30	10.5
32	12.5	5.1	32	11.1
34	13.3	5.4	34	11.9
36	14.0	5.8	36	12.6
38	14.8	6.1	38	13.3
40	15.6	6.4	40	14.0
42	16.4	6.7	42	14.7
44	17.2	7.0	44	15.4
46	17.9	7.4	46	16.1
48	18.7	7.7	48	16.8
50	19.5	8.0	50	17.5
52	20.3	8.3	52	18.2
54	21.1	8.6	54	18.9
56	21.8	9.0	56	19.6
58	22.6	9.3	58	20.3
60	23.4	9.6	60	21.0
62	24.2	9.9	62	21.7
64	25.0	10.2	64	22.4
66	25.7	10.6	66	23.1
68	26.5	10.9	68	23.8
70	27.3	11.2	70	24.5
72	28.1	11.5	72	25.2
74	28.9	11.8	74	25.9
76	29.6	12.2	76	26.6
78	30.4	12.5	78	27.3
80	31.2	12.8	80	28.0

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TABLE V.—*Standard artillery air temperatures and densities at the midpoint of the altitude zones*

Altitude	Density	Temperature
Feet	*Grains per cubic foot*	° *F.*
0	525. 9	59. 0
300	520. 9	58. 3
1, 050	508. 8	56. 8
2, 250	489. 8	54. 5
3, 750	467. 2	51. 1
5, 250	445. 6	47. 7
7, 500	415. 0	42. 3
10, 500	377. 5	34. 2
13, 500	343. 4	25. 3
16, 500	312. 3	15. 8
21, 000	270. 9	−0. 2
27, 000	224. 2	−25. 8

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TABLE VI.—*Relative humidity in percent of saturation*

Air temperature, °F.	Depression of wet-bulb thermometer in degrees F.													
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
−9	74	49	24											
−8	76	51	27	3										
−7	77	54	30	8										
−6	78	56	34	12										
−5	79	58	36	16										
−4	80	60	40	20										
−3	81	61	42	23	4									
−2	82	63	46	27	8									
−1	82	65	48	30	13									
0	84	67	50	33	17	1								
1	84	68	52	36	21	5								
2	85	70	55	39	24	9								
3	85	71	56	42	28	13								
4	86	72	58	44	30	17	3							
5	86	73	60	46	34	20	7							
6	87	74	62	49	36	23	10							
7	88	75	62	51	38	26	14	2						
8	88	76	64	53	40	29	18	6						
9	88	77	66	55	44	32	20	10						
10	89	78	67	56	45	34	24	13	2					
11	89	79	68	58	47	37	26	16	6					
12	90	80	69	59	49	39	29	19	10	0				
13	90	80	71	61	51	41	32	23	13	4				
14	90	81	72	62	53	44	35	26	16	8				
15	91	82	73	64	55	46	37	29	20	11	2			
16	92	82	74	65	56	48	40	31	22	14	6			
17	92	83	75	66	58	50	42	34	26	17	10	1		
18	92	84	76	68	60	52	44	36	28	20	12	5		
19	92	84	76	69	62	53	46	38	30	23	16	8		
20	92	85	77	70	62	55	48	40	33	26	19	12	5	
21	92	85	78	71	63	56	49	42	35	28	21	15	8	1
22	93	86	78	71	65	58	51	44	37	31	24	17	11	4
23	93	86	79	72	66	59	52	46	39	33	26	20	14	7
24	93	87	80	73	67	60	54	47	41	35	29	22	16	10
25	94	87	81	74	68	62	55	49	43	37	31	25	19	13
26	94	87	81	75	69	63	57	51	45	39	33	27	21	16
27	94	88	82	76	70	64	58	52	47	41	35	29	24	18
28	94	88	82	76	71	65	59	54	48	43	37	32	26	21
29	94	88	83	77	72	66	60	55	50	44	39	34	28	23
30	94	89	83	78	73	67	62	56	51	46	41	36	31	26

NOTE.—Enter table to the nearest half degree for both arguments. Obtain relative humidity to the nearest whole percent. Interpolate if necessary.

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TABLE VI.—*Relative humidity in percent of saturation*—Continued

Air temperature, ° F.	Depression of wet-bulb thermometer in degrees F.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
30	89	78	67	56	46	36	26	16	6						
32	89	79	69	59	49	39	30	20	11	2					
34	90	81	71	62	52	43	34	25	16	8					
36	91	82	73	64	55	46	38	29	21	13	5				
38	91	83	75	66	58	50	42	33	25	17	10	2			
40	92	83	75	68	60	52	45	37	29	22	15	7	0		
42	92	85	77	69	62	55	47	40	33	26	19	12	5		
44	93	85	78	71	63	56	49	43	36	30	23	16	10	4	
46	93	86	79	72	65	58	52	45	39	32	26	20	14	8	2
48	93	86	79	73	66	60	54	47	41	35	29	23	18	12	7
50	93	87	80	74	67	61	55	49	43	38	32	27	21	16	10
52	94	87	81	75	69	63	57	51	46	40	35	29	24	19	14
54	94	88	82	76	70	64	59	53	48	42	37	32	27	22	17
56	94	88	82	76	71	65	60	55	50	44	39	34	30	25	20
58	94	88	83	77	72	66	61	56	51	46	41	37	32	27	23
60	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26
62	94	89	84	79	74	69	64	59	54	50	45	41	36	32	28
64	95	90	84	79	74	70	65	60	56	51	47	43	38	34	30
66	95	90	85	80	75	71	66	61	57	53	48	44	40	36	32
68	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36
72	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38
74	95	91	86	82	78	74	69	65	61	58	54	50	47	43	39
76	96	91	87	82	78	74	70	66	62	59	55	51	48	44	41
78	96	91	87	83	79	75	71	67	63	60	56	53	49	46	43
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44
82	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45
84	96	92	88	84	80	76	73	69	66	62	59	56	52	49	46
86	96	92	88	84	81	77	73	70	66	63	60	57	53	50	47
88	96	92	88	85	81	77	74	70	67	64	61	57	54	51	48
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49
92	96	92	89	85	82	78	75	72	68	65	62	59	56	53	50
94	96	93	89	85	82	79	75	72	69	66	63	60	57	54	51
96	96	93	89	86	82	79	76	73	69	66	63	61	58	55	52
98	96	93	89	86	83	79	76	73	70	67	64	61	58	56	53
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54
102	96	93	90	86	83	80	77	74	71	68	65	62	60	57	55
104	97	93	90	87	83	80	77	74	71	69	66	63	60	58	55
106	97	93	90	87	84	81	78	75	72	69	66	64	61	58	56
108	97	93	90	87	84	81	78	75	72	70	67	64	62	59	57

NOTE.—Enter table to the nearest half degree for both arguments. Obtain relative humidity to the nearest whole percent. Interpolate if necessary.

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TABLE VI.—*Relative humidity in percent of saturation*—Continued

Air temperature, ° F.	Depression of wet-bulb thermometer in degrees F.														
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
46	2														
48	7	1													
50	10	5	0												
52	14	9	4												
54	17	12	8	3											
56	20	16	11	7	2										
58	23	18	14	10	6	1									
60	26	21	17	13	9	5	1								
62	28	24	20	16	12	8	4	1							
64	30	26	22	18	15	11	7	4	0						
66	32	29	25	21	17	14	10	7	3	0					
68	34	31	27	23	20	16	13	10	6	3					
70	36	33	29	25	22	19	15	12	9	6	3				
72	38	34	31	28	24	21	18	15	12	9	6	3			
74	39	36	33	29	26	23	20	17	14	11	8	5	3		
76	41	38	34	31	28	25	22	19	16	13	11	8	5	3	
78	43	39	36	33	30	27	24	21	18	16	13	10	8	5	
80	44	41	38	35	32	29	26	23	20	18	15	12	10	7	5
82	45	42	39	36	33	30	28	25	22	20	17	14	12	10	7
84	46	43	40	37	35	32	29	26	24	21	19	16	14	12	9
86	47	44	42	39	36	33	31	28	26	23	21	18	16	14	11
88	48	46	43	40	37	35	32	30	27	25	22	20	18	15	13
90	49	47	44	41	39	36	34	31	29	26	24	22	19	17	15
92	50	48	45	42	40	37	35	32	30	28	25	23	21	19	17
94	51	49	46	43	41	38	36	33	31	29	27	24	22	20	18
96	52	50	47	44	42	39	37	35	32	30	28	26	24	22	20
98	53	50	48	45	43	40	38	36	34	32	29	27	25	23	21
100	54	51	49	46	44	41	39	37	35	33	30	28	26	24	22
102	55	52	49	47	45	42	40	38	36	34	32	30	28	26	24
104	55	53	50	48	46	43	41	39	37	35	33	31	29	27	25
106	56	53	51	49	46	44	42	40	38	36	34	32	30	28	26
108	57	54	52	49	47	45	43	41	39	37	35	33	31	29	27

NOTE.—Enter table to the nearest half degree for both arguments. Obtain relative humidity to the nearest whole percent. Interpolate if necessary.

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TABLE VII.—*Air density in percent of standard when relative humidity is 78 percent*

[Results given in this table assume a relative humidity of 78 percent for all pressures and temperatures. To obtain corrections to be applied to results obtained from this table when relative humidity is other than 78 percent, see table VIII]

Pressure	Temperature, degrees F.										
	−20	−16	−12	−8	−4	0	4	8	12	16	20
27.00	108. 3	107. 4	106. 5	105. 5	104. 6	103. 7	102. 8	102. 0	101. 1	100. 2	99. 3
27.10	108. 7	107. 8	106. 9	105. 9	105. 0	104. 1	103. 2	102. 3	101. 4	100. 6	99. 7
27.20	109. 2	108. 2	107. 3	106. 3	105. 4	104. 5	103. 6	102. 7	101. 8	100. 9	100. 0
27.30	109. 6	108. 6	107. 7	106. 7	105. 8	104. 9	104. 0	103. 1	102. 2	101. 3	100. 4
27. 40	110. 0	109. 0	108. 1	107. 1	106. 2	105. 3	104. 4	103. 5	102. 5	101. 7	100. 8
27.50	110. 4	109. 4	108. 5	107. 5	106. 6	105. 6	104. 7	103. 8	102. 9	102. 0	101. 2
27.60	110. 8	109. 8	108. 9	107. 9	107. 0	106. 0	105. 1	104. 2	103. 3	102. 4	101. 5
27.70	111. 2	110. 2	109. 2	108. 3	107. 3	106. 4	105. 5	104. 6	103. 7	102. 8	101. 9
27.80	111. 6	110. 6	109. 6	108. 7	107. 7	106. 8	105. 9	105. 0	104. 1	103. 1	102. 3
27.90	112. 0	111. 0	110. 0	109. 1	108. 1	107. 2	106. 3	105. 4	104. 4	103. 5	102. 6
28.00	112. 4	111. 4	110. 4	109. 5	108. 5	107. 6	106. 7	105. 7	104. 8	103. 9	103. 0
28.10	112. 8	111. 8	110. 8	109. 8	108. 9	108. 0	107. 0	106. 1	105. 2	104. 3	103. 4
28.20	113. 2	112. 2	111. 2	110. 2	109. 3	108. 4	107. 4	106. 5	105. 6	104. 6	103. 7
28.30	113. 6	112. 6	111. 6	110. 6	109. 6	108. 7	107. 8	106. 8	105. 9	105. 0	104. 1
28.40	114. 0	113. 0	112. 0	111. 0	110. 0	109. 1	108. 2	107. 2	106. 3	105. 4	104. 4
28.50	114. 4	113. 4	112. 4	111. 4	110. 4	109. 5	108. 6	107. 6	106. 7	105. 8	104. 9
28.60	114. 8	113. 8	112. 8	111. 8	110. 8	109. 9	108. 9	108. 0	107. 0	106. 1	105. 2
28.70	115. 2	114. 2	113. 2	112. 2	111. 2	110. 3	109. 3	108. 4	107. 4	106. 5	105. 6
28.80	115. 6	114. 6	113. 6	112. 6	111. 6	110. 6	109. 7	108. 8	107. 8	106. 9	106. 0
28.90	116. 0	115. 0	114. 0	113. 0	112. 0	111. 0	110. 1	109. 1	108. 2	107. 3	106. 4
29.00	116. 4	115. 4	114. 4	113. 4	112. 4	111. 4	110. 5	109. 5	108. 6	107. 6	106. 7
29.10	116. 8	115. 8	114. 8	113. 8	112. 8	111. 8	110. 9	109. 9	109. 0	108. 0	107. 1
29.20	117. 2	116. 2	115. 2	114. 1	113. 2	112. 2	111. 2	110. 3	109. 3	108. 4	107. 4
29.30	117. 6	116. 6	115. 6	114. 5	113. 6	112. 6	111. 6	110. 7	109. 7	108. 7	107. 8
29.40	118. 0	117. 0	116. 0	114. 9	113. 9	113. 0	112. 0	111. 0	110. 1	109. 1	108. 2
29.50	118. 4	117. 4	116. 4	115. 3	114. 3	113. 4	112. 4	111. 4	110. 4	109. 5	108. 5
29.60	118. 8	117. 8	116. 7	115. 7	114. 7	113. 7	112. 8	111. 8	110. 8	109. 9	108. 9
29.70	119. 2	118. 2	117. 1	116. 1	115 1	114. 1	113. 1	112. 1	111. 2	110. 2	109. 3
29.80	119. 6	118. 6	117. 5	116. 5	115. 5	114. 5	113. 5	112. 5	111. 6	110. 6	109. 6
29.90	120. 0	119. 0	117. 9	116. 9	115. 9	114. 9	113. 9	112. 9	112. 0	111. 0	110. 0
30.00	120. 4	119. 4	118. 3	117. 3	116. 2	115. 3	114. 3	113. 3	112. 3	111. 4	110. 4
30.10	120. 8	119. 8	118. 7	117. 6	116. 6	115. 6	114. 6	113. 7	112. 7	111. 7	110. 7
30.20	121. 2	120. 2	119. 1	118. 0	117. 0	116. 0	115. 0	114. 0	113. 0	112. 1	111. 1
30.30	121. 6	120. 6	119. 5	118. 4	117. 4	116. 4	115. 4	114. 4	113. 4	112. 5	111. 4
30.40	122. 0	121. 0	119. 9	118. 8	117. 8	116. 8	115. 8	114. 8	113. 8	112. 8	111. 8
30.50	122. 4	121. 4	120. 3	119. 2	118. 2	117. 2	116. 2	115. 2	114. 2	113. 2	112. 2
30.60	122. 8	121. 8	120. 7	119. 6	118. 6	117. 5	116. 5	115. 5	114. 5	113. 5	112. 6
30.70	123. 2	122. 2	121. 0	120. 0	119. 0	117. 9	116. 9	115. 9	114. 9	113. 9	112. 9
30.80	123. 6	122. 6	121. 4	120. 4	119. 3	118. 3	117. 3	116. 3	115. 3	114. 3	113. 3
30.90	124. 0	123. 0	121. 8	120. 7	119. 7	118. 7	117. 7	116. 7	115. 6	114. 6	113. 6
31.00	124. 4	123. 4	122. 2	121. 1	120. 1	119. 1	118. 0	117. 0	116. 0	115. 0	114. 0

NOTE.—Enter table with temperature to the nearest whole degree and pressure to the nearest hundredth of an inch. Obtain air density to the nearest tenth of a percent. Interpolate if necessary.

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TABLE VII.—*Air density in percent of standard when relative humidity is 78 percent*—Continued

Pressure	Temperature, degrees F.										
	20	24	28	32	36	40	44	48	52	56	60
27.00	99.3	98.5	97.6	96.8	96.0	95.2	94.4	93.6	92.8	92.0	91.2
27.10	99.7	98.9	98.0	97.2	96.4	95.6	94.8	94.0	93.1	92.3	91.6
27.20	100.0	99.2	98.4	97.5	96.7	95.9	95.1	94.3	93.5	92.7	91.9
27.30	100.4	99.6	98.7	97.9	97.1	96.3	95.5	94.7	93.8	93.0	92.2
27.40	100.8	100.1	99.1	98.2	97.4	96.6	95.8	95.0	94.2	93.4	92.6
27.50	101.2	100.3	99.4	98.6	97.8	96.9	96.1	95.3	94.5	93.7	92.9
27.60	101.5	100.7	99.8	99.0	98.2	97.3	96.5	95.7	94.9	94.1	93.3
27.70	101.9	101.0	100.2	99.3	98.5	97.7	96.9	96.0	95.2	94.4	93.6
27.80	102.3	101.4	100.5	99.7	98.9	98.0	97.2	96.4	95.6	94.8	93.9
27.90	102.6	101.8	100.9	100.0	99.2	98.4	97.6	96.7	95.9	95.1	94.3
28.00	103.0	102.2	101.3	100.4	99.6	98.7	97.9	97.1	96.3	95.4	94.6
28.10	103.4	102.5	101.6	100.7	99.9	99.1	98.3	97.4	96.6	95.8	95.0
28.20	103.7	102.9	102.0	101.1	100.3	99.4	98.6	97.8	97.0	96.1	95.3
28.30	104.1	103.3	102.4	101.5	100.7	99.8	99.0	98.1	97.3	96.5	95.7
28.40	104.4	103.6	102.7	101.8	101.0	100.1	99.3	98.5	97.6	96.8	96.0
28.50	104.9	104.0	103.1	102.2	101.4	100.5	99.7	98.8	98.0	97.1	96.3
28.60	105.2	104.3	103.4	102.5	101.7	100.8	100.0	99.2	98.3	97.5	96.7
28.70	105.6	104.7	103.8	102.9	102.1	101.2	100.3	99.5	98.7	97.8	97.0
28.80	106.0	105.1	104.2	103.3	102.4	101.6	100.7	99.9	99.0	98.2	97.4
28.90	106.4	105.5	104.5	103.6	102.8	101.9	101.1	100.2	99.4	98.5	97.7
29.00	106.7	105.8	104.9	104.0	103.2	102.3	101.4	100.6	99.7	98.9	98.1
29.10	107.1	106.2	105.2	104.3	103.5	102.6	101.8	100.9	100.1	99.2	98.4
29.20	107.4	106.6	105.6	104.7	103.9	103.0	102.1	101.3	100.4	99.5	98.7
29.30	107.8	106.9	106.0	105.1	104.2	103.3	102.5	101.6	100.8	99.9	99.1
29.40	108.2	107.3	106.3	105.4	104.6	103.7	102.8	102.0	101.1	100.2	99.4
29.50	108.5	107.6	106.7	105.8	104.9	104.0	103.2	102.3	101.4	100.6	99.7
29.60	108.9	108.0	107.0	106.2	105.3	104.4	103.5	102.6	101.8	100.9	100.1
29.70	109.3	108.4	107.4	106.5	105.6	104.7	103.9	103.0	102.1	101.2	100.4
29.80	109.6	108.7	107.8	106.9	106.0	105.1	104.2	103.3	102.5	101.6	100.8
29.90	110.0	109.1	108.2	107.3	106.4	105.5	104.6	103.7	102.8	102.0	101.1
30.00	110.4	109.5	108.5	107.6	106.7	105.8	104.9	104.0	103.2	102.3	101.4
30.10	110.7	109.8	108.8	107.9	107.1	106.2	105.3	104.4	103.5	102.6	101.8
30.20	111.1	110.2	109.2	108.3	107.4	106.5	105.6	104.7	103.8	103.0	102.1
30.30	111.4	110.6	109.6	108.7	107.8	106.9	106.0	105.1	104.2	103.3	102.4
30.40	111.8	110.9	109.9	109.0	108.1	107.2	106.3	105.4	104.5	103.6	102.8
30.50	112.2	111.3	110.3	109.4	108.5	107.6	106.6	105.7	104.8	104.0	103.1
30.60	112.6	111.6	110.6	109.7	108.8	107.9	107.0	106.1	105.2	104.3	103.4
30.70	112.9	112.0	111.0	110.1	109.2	108.2	107.3	106.4	105.5	104.6	103.8
30.80	113.3	112.4	111.4	110.4	109.5	108.6	107.7	106.8	105.9	105.0	104.1
30.90	113.6	112.7	111.7	110.8	109.9	108.9	108.0	107.1	106.2	105.3	104.4
31.00	114.0	113.1	112.1	111.2	110.2	109.3	108.4	107.5	106.6	105.7	104.8

NOTE.—Enter table with temperature to the nearest whole degree and pressure to the nearest hundredth of an inch. Obtain air density to the nearest tenth of a percent. Interpolate if necessary.

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TABLE VII.—*Air density in percent of standard when relative humidity is 78 percent*—Continued

Pressure	Temperature, degrees F.										
	60	64	68	72	76	80	84	88	92	96	100
27.00	91.2	90.5	89.7	88.9	88.1	87.3	86.5	85.7	84.9	84.1	83.3
27.10	91.6	90.8	90.0	89.2	88.4	87.6	86.8	86.0	85.2	84.4	83.6
27.20	91.9	91.1	90.3	89.6	88.8	87.9	87.1	86.3	85.5	84.7	83.9
27.30	92.2	91.5	90.7	89.9	89.1	88.3	87.5	86.7	85.9	85.1	84.2
27.40	92.6	91.8	91.0	90.2	89.4	88.6	87.8	87.0	86.2	85.4	84.5
27.50	92.9	92.1	91.3	90.6	89.8	88.9	88.1	87.3	86.5	85.7	84.9
27.60	93.3	92.5	91.7	90.9	90.1	89.3	88.5	87.7	86.8	86.0	85.2
27.70	93.6	92.8	92.0	91.2	90.4	89.6	88.8	88.0	87.2	86.3	85.5
27.80	93.9	93.1	92.3	91.5	90.7	89.9	89.1	88.3	87.5	86.7	85.9
27.90	94.3	93.5	92.7	91.9	91.1	90.3	89.5	88.6	87.8	87.0	86.1
28.00	94.6	93.8	93.0	92.2	91.4	90.6	89.8	89.0	88.1	87.3	86.4
28.10	95.0	94.2	93.3	92.5	91.7	90.9	90.1	89.3	88.4	87.6	86.7
28.20	95.3	94.5	93.7	92.9	92.1	91.2	90.4	89.6	88.8	87.9	87.1
28.30	95.7	94.9	94.0	93.2	92.4	91.6	90.8	89.9	89.1	88.3	87.4
28.40	96.0	95.2	94.4	93.6	92.7	91.9	91.1	90.3	89.4	88.6	87.7
28.50	96.3	95.5	94.7	93.9	93.1	92.2	91.4	90.6	89.7	88.9	88.0
28.60	96.7	95.9	95.0	94.2	93.4	92.6	91.8	90.9	90.1	89.2	88.3
28.70	97.0	96.2	95.4	94.6	93.7	92.9	92.1	91.2	90.4	89.5	88.6
28.80	97.4	96.5	95.7	94.9	94.1	93.2	92.4	91.5	90.7	89.9	89.0
28.90	97.7	96.9	96.1	95.2	94.4	93.5	92.7	91.9	91.0	90.2	89.3
29.00	98.1	97.2	96.4	95.6	94.7	93.9	93.1	92.2	91.4	90.5	89.6
29.10	98.4	97.6	96.7	95.9	95.1	94.2	93.4	92.5	91.7	90.8	90.0
29.20	98.7	97.9	97.0	96.2	95.4	94.5	93.7	92.9	92.0	91.1	90.3
29.30	99.1	98.2	97.4	96.6	95.7	94.8	94.0	93.2	92.3	91.5	90.6
29.40	99.4	98.6	97.7	96.9	96.1	95.2	94.4	93.5	92.6	91.8	90.9
29.50	99.7	98.9	98.1	97.2	96.4	95.5	94.7	93.8	92.9	92.1	91.2
29.60	100.1	99.2	98.4	97.6	96.7	95.8	95.0	94.1	93.3	92.4	91.5
29.70	100.4	99.6	98.7	97.9	97.0	96.2	95.3	94.5	93.6	92.7	91.8
29.80	100.8	99.9	99.0	98.2	97.4	96.5	95.7	94.8	93.9	93.0	92.2
29.90	101.1	100.3	99.4	98.6	97.7	96.8	96.0	95.1	94.3	93.4	92.5
30.00	101.4	100.6	99.7	98.9	98.0	97.1	96.3	95.5	94.6	93.7	92.8
30.10	101.8	100.9	100.0	99.2	98.4	97.5	96.7	95.8	94.9	94.0	93.1
30.20	102.1	101.3	100.4	99.6	98.7	97.8	97.0	96.1	95.2	94.3	93.4
30.30	102.4	101.6	100.7	99.9	99.0	98.1	97.3	96.4	95.5	94.6	93.7
30.40	102.8	101.9	101.1	100.2	99.3	98.4	97.6	96.7	95.8	94.9	94.0
30.50	103.1	102.3	101.4	100.5	99.7	98.8	97.9	97.0	96.2	95.3	94.3
30.60	103.4	102.6	101.7	100.9	100.0	99.1	98.3	97.4	96.5	95.6	94.6
30.70	103.8	102.9	102.0	101.2	100.3	99.4	98.6	97.7	96.8	95.9	94.9
30.80	104.1	103.3	102.4	101.5	100.6	99.7	98.9	98.0	97.1	96.2	95.3
30.90	104.4	103.6	102.7	101.9	101.0	100.1	99.2	98.3	97.4	96.5	95.6
31.00	104.8	103.9	103.0	102.2	101.3	100.4	99.5	98.6	97.7	96.8	95.9

NOTE.—Enter table with temperature to the nearest whole degree and pressure to the nearest hundredth of an inch. Obtain air density to the nearest tenth of a percent. Interpolate if necessary.

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TABLE VIII.—*Air density corrections to be applied to table VII when relative humidity is other than 78 percent*

Relative humidity	Temperature, degrees F.						
	20	0	20	40	60	80	100
0	0	0	+0. 1	+0. 3	+0. 5	+1. 0	+1. 8
10	0	0	+0. 1	+0. 2	+0. 4	+0. 9	+1. 6
20	0	0	+0. 1	+0. 2	+0. 4	+0. 7	+1. 3
30	0	0	+0. 1	+0. 2	+0. 3	+0. 6	+1. 1
40	0	0	0	+0. 1	+0. 2	+0. 5	+0. 9
50	0	0	0	+0. 1	+0. 2	+0. 3	+0. 6
60	0	0	0	+0. 1	+0. 1	+0. 2	+0. 4
70	0	0	0	0	0	+0. 1	+0. 2
80	0	0	0	0	0	0	0
90	0	0	0	0	−0. 1	−0. 2	−0. 3
100	0	0	0	0	−0. 2	−0. 3	−0. 5

TABLE IX.—*Air density weighting factors for antiaircraft and other high-angle fire*

Standard altitude (feet)	Zones										
	0 to 600	600 to 1,500	1,500 to 3,000	3,000 to 4,500	4,500 to 6,000	6,000 to 9,000	9,000 to 12,000	12,000 to 15,000	15,000 to 18,000	18,000 to 24,000	24,000 to 30,000
600	1. 00										
1,500	. 63	0. 37									
3,000	. 37	. 37	0. 26								
4,500	. 25	. 30	. 35	0. 10							
6,000	. 20	. 24	. 30	. 18	0. 08						
9,000	. 13	. 19	. 24	. 18	. 14	0. 12					
12,000	. 10	. 14	. 20	. 16	. 14	. 19	0. 07				
15,000	. 09	. 10	. 17	. 15	. 13	. 20	. 12	0. 04			
18,000	. 07	. 09	. 14	. 13	. 12	. 19	. 15	. 08	0. 03		
24,000	. 05	. 08	. 12	. 10	. 10	. 17	. 14	. 10	. 08	0. 06	
30,000	. 04	. 06	. 10	. 08	. 08	. 15	. 13	. 10	. 10	. 12	0. 04

NOTE.—The above air density weighting factors were furnished by the Ordnance Department. These air density weighting factors are used in the preparation of table X. Table X is used in preparing "message 2."

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INSTRUCTIONS FOR USING TABLE X

Table X is used to determine ballistic densities for "message 2." The weighting factors in table IX were used in computing table X.

The arguments used in entering table X are the surface air density at the meteorological station, and the elevation of the station above sea level in hundreds of feet. Ballistic densities obtained from this table are recorded to the nearest whole percent.

When the station elevation in hundreds of feet is between 0 and 1,000 or between 1,000 and 2,000, interpolation between appropriate vertical groups is necessary. When the station elevation is more than 2,000 feet, the data for 2,000 feet are used.

The following example illustrates the use of table X: The surface air density at the meteorological station is 93 percent. The station elevation is 960 feet above sea level. Entering the table with 1,000 feet as the station elevation, the ballistic densities in percent are found in the vertical group headed by 93, to be 93.2, 93.3, 93.6, 93.8, and so on, for the first, second, third, fourth, and so on, standard altitudes. These values are recorded as 93, 93, 94, 94, and so on.

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TABLE X.—*Ballistic densities in percent of standard for antiaircraft and other high-angle fire*

Standard altitude (feet)	Station elevation in feet above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
Surface		85.0	85.0		86.0	86.0		87.0	87.0
600		85.4	85.2		86.4	86.2		87.3	87.2
1,500		85.7	85.6		86.7	86.5		87.6	87.4
3,000		86.4	86.1		87.3	87.0		88.2	87.9
4,500		87.0	86.6		87.8	87.4		88.7	88.3
6,000		87.6	87.1		88.4	87.9		89.2	88.7
9,000		88.6	87.9		89.3	88.6		90.0	89.3
12,000		89.5	88.6		90.2	89.2		90.8	89.9
15,000		90.2	89.1		90.8	89.7		91.4	90.3
18,000		90.9	89.6		91.5	90.2		92.0	90.7
24,000		91.8	90.3		92.3	90.8		92.8	91.2
30,000		92.7	90.9		93.1	91.3		93.5	91.7
Surface	88.0	88.0	88.0	89.0	89.0	89.0	90.0	90.0	90.0
600	88.3	88.3	88.2	89.3	89.3	89.1	90.2	90.3	90.1
1,500	88.6	88.6	88.4	89.6	89.5	89.3	90.6	90.5	90.3
3,000	89.2	89.1	88.8	90.2	90.0	89.7	91.1	90.9	90.6
4,500	89.8	89.5	89.1	90.7	90.4	90.0	91.5	91.3	90.8
6,000	90.4	90.0	89.5	91.2	90.8	90.3	92.0	91.6	91.0
9,000	91.4	90.8	90.0	92.2	91.5	90.7	92.9	92.3	91.5
12,000	92.3	91.5	90.5	93.0	92.2	91.2	93.7	92.8	91.8
15,000	93.1	92.0	90.9	93.7	92.7	91.5	94.3	93.3	92.1
18,000	93.8	92.6	91.3	94.4	93.2	91.8	94.9	93.7	92.4
24,000	94.7	93.3	91.7	95.2	93.8	92.2	95.7	94.3	92.7
30,000	95.6	93.9	92.2	96.1	94.4	92.6	96.5	94.8	93.0
Surface	91.0	91.0	91.0	92.0	92.0	92.0	93.0	93.0	93.0
600	91.2	91.2	91.1	92.2	92.2	92.0	93.2	93.2	93.0
1,500	91.5	91.4	91.2	92.5	92.4	92.1	93.4	93.3	93.1
3,000	92.0	91.8	91.4	92.9	92.7	92.3	93.8	93.6	93.2
4,500	92.4	92.1	91.6	93.3	93.0	92.5	94.2	93.8	93.3
6,000	92.9	92.4	91.8	93.7	93.2	92.6	94.5	94.1	93.4
9,000	93.7	93.0	92.2	94.4	93.7	92.9	95.2	94.5	93.6
12,000	94.4	93.5	92.5	95.1	94.2	93.2	95.8	94.8	93.8
15,000	95.0	93.9	92.7	95.6	94.5	93.3	96.2	95.1	93.9
18,000	95.5	94.3	93.0	96.1	94.9	93.5	96.7	95.4	94.1
24,000	96.3	94.8	93.2	96.8	95.3	93.7	97.3	95.8	94.2
30,000	97.0	95.2	93.4	97.4	95.6	93.8	97.8	96.1	94.2

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TABLE X.—*Ballistic densities in percent of standard for antiaircraft and other high angle fire*—Continued

Standard altitude (feet)	Station elevation in feet above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
Surface	94.0	94.0	94.0	95.0	95.0	95.0	96.0	96.0	96.0
600	94.2	94.2	94.0	95.1	95.1	95.0	96.1	96.1	95.9
1,500	94.4	94.3	94.0	95.3	95.2	95.0	96.3	96.2	95.9
3,000	94.7	94.5	94.1	95.6	95.4	95.0	96.6	96.3	95.9
4,500	95.0	94.7	94.2	95.9	95.5	95.0	96.8	96.4	95.9
6,000	95.4	94.9	94.2	96.2	95.7	95.0	97.0	96.5	95.8
9,000	95.9	95.2	94.4	96.7	95.9	95.1	97.5	96.7	95.8
12,000	96.5	95.5	94.5	97.2	96.2	95.1	97.8	96.8	95.8
15,000	96.9	95.8	94.5	97.5	96.4	95.2	98.1	97.0	95.8
18,000	97.3	96.0	94.6	97.9	96.6	95.2	98.4	97.1	95.7
24,000	97.8	96.3	94.7	98.3	96.8	95.2	98.8	97.3	95.7
30,000	98.3	96.5	94.7	98.7	96.9	95.1	99.2	97.4	95.5
Surface	97.0	97.0	97.0	98.0	98.0	98.0	99.0	99.0	99.0
600	97.1	97.1	96.9	98.1	98.1	97.9	99.1	99.0	98.8
1,500	97.2	97.1	96.9	98.2	98.1	97.8	99.2	99.0	98.7
3,000	97.5	97.2	96.8	98.4	98.1	97.7	99.3	99.0	98.5
4,500	97.7	97.2	96.7	98.5	98.1	97.5	99.4	98.9	98.4
6,000	97.9	97.3	96.6	98.7	98.1	97.4	99.5	98.9	98.2
9,000	98.2	97.4	96.5	99.0	98.1	97.2	99.7	98.9	98.0
12,000	98.5	97.5	96.4	99.2	98.2	97.1	99.9	98.9	97.7
15,000	98.8	97.6	96.4	99.4	98.2	97.0	100.1	98.8	97.6
18,000	99.0	97.7	96.3	99.6	98.3	96.9	100.2	98.8	97.4
24,000	99.3	97.8	96.2	99.8	98.3	96.6	100.4	98.8	97.1
30,000	99.6	97.8	95.9	100.0	98.2	96.3	100.5	98.6	96.7
Surface	100.0	100.0	100.0	101.0	101.0	101.0	102.0	102.0	102.0
600	100.0	100.0	99.8	101.0	101.0	100.8	102.0	102.0	101.8
1,500	100.1	100.0	99.7	101.1	100.9	100.6	102.0	101.9	101.6
3,000	100.2	99.9	99.4	101.1	100.8	100.3	102.0	101.7	101.2
4,500	100.3	99.8	99.2	101.2	100.6	100.1	102.0	101.5	100.9
6,000	100.4	99.7	99.0	101.2	100.5	99.8	102.0	101.3	100.6
9,000	100.5	99.6	98.7	101.2	100.3	99.4	102.0	101.1	100.1
12,000	100.6	99.5	98.4	101.3	100.2	99.1	102.0	100.9	99.7
15,000	100.7	99.5	98.2	101.3	100.1	98.8	102.0	100.7	99.4
18,000	100.8	99.4	98.0	101.4	100.0	98.5	101.9	100.5	99.1
24,000	100.9	99.3	97.6	101.4	99.8	98.1	101.9	100.3	98.6
30,000	100.9	99.1	97.2	101.4	99.5	97.6	101.8	99.9	98.0

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TABLE X.—*Ballistic densities in percent of standard for antiaircraft and other high-angle fire*—Continued

Standard altitude (feet)	Station elevation in feet above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
Surface	103. 0	103. 0	103. 0	104. 0	104. 0	104. 0	105. 0	105. 0	105. 0
600	103. 0	103. 0	102. 7	104. 0	103. 9	103. 7	104. 9	104. 9	104. 7
1,500	103. 0	102. 8	102. 5	103. 9	103. 8	103. 4	104. 9	104. 7	104. 4
3,000	103. 0	102. 6	102. 1	103. 9	103. 5	103. 0	104. 8	104. 4	103. 9
4,500	102. 9	102. 4	101. 8	103. 8	103. 2	102. 6	104. 7	104. 1	103. 4
6,000	102. 9	102. 2	101. 4	103. 7	103. 0	102. 2	104. 5	103. 8	103. 0
9,000	102. 8	101. 8	100. 9	103. 5	102. 6	101. 6	104. 3	103. 3	102. 3
12,000	102. 7	101. 5	100. 4	103. 3	102. 2	101. 0	104. 0	102. 9	101. 7
15,000	102. 6	101. 3	100. 0	103. 2	101. 9	100. 6	103. 9	102. 5	101. 2
18,000	102. 5	101. 1	99. 6	103. 1	101. 7	100. 2	103. 7	102. 2	100. 8
24,000	102. 4	100. 8	99. 1	102. 9	101. 3	99. 6	103. 4	101. 8	100. 1
30,000	102. 2	100. 4	98. 4	102. 7	100. 8	98. 8	103. 1	101. 2	99. 2
Surface	106. 0	106. 0	106. 0	107. 0	107. 0	107. 0	108. 0	108. 0	108. 0
600	105. 9	105. 9	105. 6	106. 9	106. 9	106. 6	107. 9	107. 8	107. 6
1,500	105. 9	105. 7	105. 3	106. 8	106. 6	106. 3	107. 8	107. 6	107. 2
3,000	105. 7	105. 3	104. 8	106. 6	106. 2	105. 6	107. 5	107. 1	106. 5
4,500	105. 5	104. 9	104. 3	106. 4	105. 8	105. 1	107. 3	106. 6	106. 0
6,000	105. 4	104. 6	103. 8	106. 2	105. 4	104. 6	107. 0	106. 2	105. 4
9,000	105. 0	104. 0	103. 0	105. 8	104. 8	103. 8	106. 5	105. 5	104. 5
12,000	104. 7	103. 5	102. 3	105. 4	104. 2	103. 0	106. 1	104. 9	103. 7
15,000	104. 5	103. 2	101. 8	105. 1	103. 8	102. 4	105. 8	104. 4	103. 0
18,000	104. 3	102. 8	101. 3	104. 9	103. 4	101. 9	105. 4	103. 9	102. 4
24,000	104. 0	102. 3	100. 6	104. 5	102. 8	101. 1	105. 0	103. 3	101. 6
30,000	103. 6	101. 6	99. 7	104. 0	102. 1	100. 1	104. 4	102. 5	100. 5
Surface	109. 0	109. 0	109. 0	110. 0	110. 0	110. 0	111. 0	111. 0	111. 0
600	108. 9	108. 8	108. 6	109. 8	109. 8	109. 5	110. 8	110. 8	110. 5
1,500	108. 7	108. 5	108. 1	109. 7	109. 5	109. 1	110. 6	110. 4	110. 0
3,000	108. 4	108. 0	107. 4	109. 4	108. 9	108. 3	110. 3	109. 7	109. 2
4,500	108. 2	107. 5	106. 8	109. 0	108. 3	107. 7	109. 9	109. 2	108. 5
6,000	107. 8	107. 0	106. 2	108. 7	107. 8	107. 0	109. 5	108. 6	107. 8
9,000	107. 3	106. 2	105. 2	108. 0	107. 0	105. 9	108. 8	107. 7	106. 6
12,000	106. 8	105. 5	104. 3	107. 5	106. 2	105. 0	108. 2	106. 9	105. 6
15,000	106. 4	105. 0	103. 6	107. 0	105. 6	104. 3	107. 7	106. 2	104. 9
18,000	106. 0	104. 5	103. 0	106. 6	105. 1	103. 5	107. 2	105. 6	104. 1
24,000	105. 5	103. 8	102. 0	106. 0	104. 3	102. 5	106. 5	104. 8	103. 0
30,000	104. 9	102. 9	100. 9	105. 3	103. 4	101. 3	105. 8	103. 8	101. 7

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TABLE X.—*Ballistic densities in percent of standard for antiaircraft and other high-angle fire*—Continued

Standard altitude (feet)	Station elevation in feet above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
Surface	112.0	112.0	112.0	113.0	113.0		114.0	114.0	
600	111.8	111.7	111.5	112.8	112.7		113.7	113.7	
1,500	111.6	111.4	111.0	112.6	112.3		113.5	113.3	
3,000	111.2	110.6	110.1	112.1	111.5		113.0	112.4	
4,500	110.8	110.0	109.4	111.7	110.9		112.5	111.8	
6,000	110.3	109.5	108.6	111.2	110.3		112.0	111.1	
9,000	109.6	108.4	107.4	110.3	109.2		111.1	109.9	
12,000	108.9	107.6	106.3	109.5	108.2		110.2	108.9	
15,000	108.3	106.9	105.5	108.9	107.5		109.6	108.1	
18,000	107.8	106.2	104.7	108.3	106.8		108.9	107.3	
24,000	107.0	105.3	103.5	107.5	105.8		108.1	106.3	
30,000	106.2	104.2	102.2	106.6	104.6		107.1	105.1	
Surface	115.0	115.0		116.0	116.0		117.0	117.0	
600	114.7	114.7		115.7	115.6		116.7	116.6	
1,500	114.5	114.2		115.4	115.2		116.4	116.1	
3,000	113.9	113.3		114.9	114.2		115.8	115.1	
4,500	113.4	112.6		114.3	113.5		115.2	114.3	
6,000	112.8	111.9		113.7	112.7		114.5	113.5	
9,000	111.8	110.6		112.6	111.4		113.3	112.1	
12,000	110.9	109.6		111.6	110.2		112.3	110.9	
15,000	110.2	108.7		110.8	109.3		111.5	110.0	
18,000	109.5	107.9		110.1	108.5		110.7	109.0	
24,000	108.6	106.8		109.1	107.3		109.6	107.8	
30,000	107.5	105.5		108.0	105.9		108.4	106.3	
Surface	118.0	119.0		120.0	121.0		122.0	123.0	
600	117.7	118.6		119.6	120.6		121.6	122.6	
1,500	117.3	118.3		119.3	120.2		121.2	122.1	
3,000	116.7	117.6		118.5	119.4		120.3	121.3	
4,500	116.0	116.9		117.8	118.7		119.5	120.4	
6,000	115.3	116.2		117.0	117.8		118.7	119.5	
9,000	114.1	114.9		115.6	116.4		117.1	117.9	
12,000	113.0	113.7		114.4	115.1		115.7	116.4	
15,000	112.1	112.7		113.4	114.0		114.7	115.3	
18,000	111.3	111.8		112.4	113.0		113.6	114.2	
24,000	110.0	110.6		111.1	111.7		112.2	112.7	
30,000	108.8	109.3		109.7	110.2		110.6	111.0	

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TABLE XI.—*Air density weighting factors for low-angle fire*

Standard altitude (feet)	Zones										
	0 to 600	600 to 1,500	1,500 to 3,000	3,000 to 4,500	4,500 to 6,000	6,000 to 9,000	9,000 to 12,000	12,000 to 15,000	15,000 to 18,000	18,000 to 24,000	24,000 to 30,000
600	1. 00										
1,500	. 43	0. 57									
3,000	. 22	. 31	0. 47								
4,500	. 15	. 21	. 32	0. 32							
6,000	. 11	. 17	. 25	. 22	0. 25						
9,000	. 08	. 11	. 17	. 17	. 15	0. 32					
12,000	. 06	. 08	. 14	. 13	. 12	. 22	0. 25				
15,000	. 05	. 06	. 11	. 11	. 10	. 19	. 17	0. 21			
18,000	. 04	. 06	. 09	. 09	. 08	. 17	. 15	. 14	0. 18		
24,000	. 03	. 04	. 07	. 07	. 07	. 13	. 12	. 11	. 11	0. 25	
30,000	. 02	. 04	. 05	. 06	. 05	. 11	. 10	. 10	. 09	. 17	0. 21

NOTE.—The above air density weighting factors were furnished by the Ordnance Department. These air density weighting factors are used in the preparation of table XII. Table XII is used in preparing "message 3".

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INSTRUCTIONS FOR USING TABLE XII

Table XII is used to determine ballistic densities for "message 3." The weighting factors in table XI were used in computing table XII.

The instructions for the use of table XII are the same as the instructions for the use of table X.

TABLE XII.—*Ballistic densities in percent of standard for low-angle fire*

Standard altitude (feet)	Station elevation in feet above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
Surface	------	85. 0	85. 0	------	86. 0	86. 0	------	87. 0	87. 0
600	------	85. 4	85. 2	------	86. 4	86. 2	------	87. 3	87. 2
1,500	------	85. 9	85. 7	------	86. 9	86. 7	------	87. 8	87. 6
3,000	------	86. 9	86. 5	------	87. 7	87. 4	------	88. 6	88. 2
4,500	------	87. 7	87. 2	------	88. 5	88. 0	------	89. 3	88. 8
6,000	------	88. 5	87. 8	------	89. 2	88. 5	------	90. 0	89. 2
9,000	------	89. 8	88. 8	------	90. 4	89. 4	------	91. 1	90. 1
12,000	------	90. 9	89. 6	------	91. 5	90. 2	------	92. 0	90. 7
15,000	------	91. 7	90. 2	------	92. 3	90. 7	------	92. 8	91. 2
18,000	------	92. 4	90. 8	------	92. 9	91. 2	------	93. 3	91. 7
24,000	------	93. 4	91. 5	------	93. 8	91. 8	------	94. 2	92. 2
30,000	------	94. 2	92. 0	------	94. 5	92. 3	------	94. 8	92. 5
Surface	88. 0	88. 0	88. 0	89. 0	89. 0	89. 0	90. 0	90. 0	90. 0
600	88. 3	88. 3	88. 2	89. 3	89. 3	89. 1	90. 2	90. 3	90. 1
1,500	88. 8	88. 7	88. 5	89. 8	89. 7	89. 4	90. 7	90. 6	90. 4
3,000	89. 7	89. 5	89. 1	90. 6	90. 3	89. 9	91. 4	91. 2	90. 8
4,500	90. 5	90. 1	89. 5	91. 3	90. 9	90. 3	92. 2	91. 7	91. 1
6,000	91. 3	90. 7	90. 0	92. 1	91. 4	90. 7	92. 8	92. 2	91. 4
9,000	92. 7	91. 7	90. 7	93. 3	92. 4	91. 3	94. 0	93. 0	92. 0
12,000	93. 8	92. 6	91. 3	94. 3	93. 2	91. 8	94. 9	93. 7	92. 4
15,000	94. 7	93. 3	91. 7	95. 2	93. 8	92. 2	95. 7	94. 3	92. 7
18,000	95. 3	93. 8	92. 1	95. 8	94. 2	92. 5	96. 3	94. 7	93. 0
24,000	96. 5	94. 5	92. 6	96. 9	94. 9	92. 9	97. 2	95. 3	93. 3
30,000	97. 3	95. 1	92. 8	97. 6	95. 4	93. 1	97. 9	95. 7	93. 4
Surface	91. 0	91. 0	91. 0	92. 0	92. 0	92. 0	93. 0	93. 0	93. 0
600	91. 2	91. 2	91. 1	92. 2	92. 2	92. 0	93. 2	93. 2	93. 0
1,500	91. 7	91. 5	91. 3	92. 6	92. 5	92. 2	93. 6	93. 4	93. 1
3,000	92. 3	92. 0	91. 6	93. 2	92. 9	92. 5	94. 1	93. 8	93. 3
4,500	93. 0	92. 5	91. 9	93. 8	93. 3	92. 7	94. 6	94. 1	93. 5
6,000	93. 6	92. 9	92. 2	94. 3	93. 7	92. 9	95. 1	94. 4	93. 6
9,000	94. 6	93. 7	92. 6	95. 3	94. 3	93. 2	96. 0	95. 0	93. 9
12,000	95. 5	94. 3	93. 0	96. 1	94. 9	93. 5	96. 7	95. 4	94. 1
15,000	96. 2	94. 8	93. 2	96. 7	95. 3	93. 7	97. 3	95. 8	94. 2
18,000	96. 7	95. 1	93. 4	97. 2	95. 6	93. 9	97. 7	96. 1	94. 3
24,000	97. 6	95. 7	93. 7	98. 0	96. 0	94. 0	98. 4	96. 4	94. 4
30,000	98. 2	95. 9	93. 6	98. 5	96. 2	93. 9	98. 8	96. 5	94. 2

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TABLE XII.—*Ballistic densities in percent of standard for low-angle fire*—Continued

Standard altitude (feet)	Station elevation in feet above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
Surface	94. 0	94. 0	94. 0	95. 0	95. 0	95. 0	96. 0	96. 0	96. 0
600	94. 2	94. 2	94. 0	95. 1	95. 1	95. 0	96. 1	96. 1	95. 9
1,500	94. 5	94. 3	94. 1	95. 4	95. 3	95. 0	96. 4	96. 2	95. 9
3,000	95. 0	94. 6	94. 2	95. 9	95. 5	95. 0	96. 8	96. 4	95. 9
4,500	95. 5	94. 9	94. 3	96. 3	95. 7	95. 0	97. 1	96. 5	95. 8
6,000	95. 9	95. 2	94. 4	96. 6	95. 9	95. 1	97. 4	96. 6	95. 8
9,000	96. 6	95. 6	94. 5	97. 3	96. 2	95. 1	98. 0	96. 9	95. 8
12,000	97. 3	96. 0	94. 6	97. 9	96. 6	95. 2	98. 4	97. 1	95. 8
15,000	97. 8	96. 3	94. 7	98. 3	96. 8	95. 2	98. 8	97. 3	95. 7
18,000	98. 1	96. 5	94. 8	98. 6	97. 0	95. 2	99. 1	97. 4	95. 7
24,000	98. 8	96. 8	94. 8	99. 1	97. 1	95. 1	99. 5	97. 5	95. 5
30,000	99. 1	96. 8	94. 4	99. 4	97. 1	94. 7	99. 7	97. 4	95. 0
Surface	97. 0	97. 0	97. 0	98. 0	98. 0	98. 0	99. 0	99. 0	99. 0
600	97. 1	97. 1	96. 9	98. 1	98. 1	97. 9	99. 1	99. 0	98. 8
1,500	97. 3	97. 1	96. 8	98. 3	98. 1	97. 7	99. 2	99. 0	98. 7
3,000	97. 6	97. 2	96. 7	98. 5	98. 1	97. 6	99. 4	98. 9	98. 4
4,500	97. 9	97. 3	96. 6	98. 7	98. 1	97. 4	99. 6	98. 9	98. 2
6,000	98. 2	97. 4	96. 5	98. 9	98. 1	97. 3	99. 7	98. 9	98. 0
9,000	98. 6	97. 5	96. 4	99. 3	98. 2	97. 0	100. 0	98. 8	97. 7
12,000	99. 0	97. 7	96. 3	99. 6	98. 3	96. 9	100. 2	98. 8	97. 4
15,000	99. 3	97. 8	96. 2	99. 9	98. 3	96. 7	100. 4	98. 8	97. 2
18,000	99. 6	97. 9	96. 1	100. 0	98. 3	96. 6	100. 5	98. 8	97. 0
24,000	99. 9	97. 9	95. 8	100. 3	98. 3	96. 2	100. 7	98. 6	96. 6
30,000	100. 0	97. 7	95. 2	100. 3	97. 9	95. 5	100. 6	98. 2	95. 8
Surface	100. 0	100. 0	100. 0	101. 0	101. 0	101. 0	102. 0	102. 0	102. 0
600	100. 0	100. 0	99. 8	101. 0	101. 0	100. 8	102. 0	102. 0	101. 8
1,500	100. 2	99. 9	99. 6	101. 1	100. 9	100. 5	102. 1	101. 8	101. 4
3,000	100. 3	99. 8	99. 3	101. 2	100. 7	100. 1	102. 1	101. 5	101. 0
4,500	100. 4	99. 7	99. 0	101. 2	100. 5	99. 8	102. 0	101. 3	100. 5
6,000	100. 5	99. 6	98. 7	101. 2	100. 4	99. 5	102. 0	101. 1	100. 2
9,000	100. 6	99. 5	98. 3	101. 3	100. 1	98. 9	102. 0	100. 8	99. 6
12,000	100. 8	99. 4	98. 0	101. 4	100. 0	98. 5	101. 9	100. 5	99. 1
15,000	100. 9	99. 3	97. 7	101. 4	99. 8	98. 2	101. 9	100. 3	98. 7
18,000	101. 0	99. 2	97. 5	101. 4	99. 7	97. 9	101. 9	100. 2	98. 4
24,000	101. 1	99. 0	96. 9	101. 4	99. 4	97. 3	101. 8	99. 8	97. 7
30,000	101. 9	98. 5	96. 1	101. 2	98. 8	96. 3	101. 5	99. 1	96. 6

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TABLE XII.—*Ballistic densities in percent of standard for low-angle fire*—Continued

Standard altitude (feet)	Station elevation in feet above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
Surface	103.0	103.0	103.0	104.0	104.0	104.0	105.0	105.0	105.0
600	103.0	103.0	102.7	104.0	103.9	103.7	104.9	104.9	104.7
1,500	103.0	102.7	102.4	103.9	103.7	103.3	104.9	104.6	104.2
3,000	102.9	102.4	101.8	103.8	103.2	102.7	104.7	104.1	103.5
4,500	102.9	102.1	101.3	103.7	102.9	102.1	104.5	103.7	102.9
6,000	102.8	101.8	100.9	103.5	102.6	101.6	104.3	103.3	102.4
9,000	102.6	101.4	100.2	103.3	102.1	100.8	104.0	102.7	101.4
12,000	102.5	101.1	99.7	103.1	101.7	100.2	103.7	102.2	100.8
15,000	102.4	100.8	99.2	103.0	101.3	99.7	103.5	101.8	100.2
18,000	102.4	100.6	98.8	102.8	101.1	99.3	103.3	101.5	99.7
24,000	102.2	100.1	98.0	102.6	100.5	98.4	103.0	100.9	98.8
30,000	101.8	99.4	96.9	102.1	99.7	97.1	102.4	99.9	97.4
Surface	106.0	106.0	106.0	107.0	107.0	107.0	108.0	108.0	108.0
600	105.9	105.9	105.6	106.9	106.9	106.6	107.9	107.8	107.6
1,500	105.8	105.6	105.1	106.8	106.5	106.1	107.7	107.4	107.0
3,000	105.6	105.0	104.4	106.5	105.8	105.2	107.4	106.7	106.1
4,500	105.3	104.5	103.7	106.1	105.3	104.5	107.0	106.1	105.3
6,000	105.1	104.1	103.1	105.8	104.8	103.8	106.6	105.6	104.6
9,000	104.6	103.3	102.1	105.3	104.0	102.7	105.9	104.6	103.3
12,000	104.3	102.8	101.3	104.9	103.4	101.9	105.4	103.9	102.4
15,000	104.0	102.3	100.7	104.5	102.8	101.2	105.0	103.3	101.7
18,000	103.8	102.0	100.2	104.2	102.4	100.6	104.7	102.9	101.1
24,000	103.3	101.3	99.1	103.7	101.6	99.5	104.1	102.0	99.8
30,000	102.7	100.2	97.7	103.0	100.5	97.9	103.3	100.8	98.2
Surface	109.0	109.0	109.0	110.0	110.0	110.0	111.0	111.0	111.0
600	108.9	108.8	108.6	109.8	109.8	109.5	110.8	110.8	110.5
1,500	108.7	108.4	107.9	109.6	109.3	108.8	110.6	110.2	109.8
3,000	108.2	107.5	106.9	109.1	108.4	107.8	110.0	109.3	108.6
4,500	107.8	106.9	106.0	108.6	107.7	106.8	109.4	108.5	107.6
6,000	107.4	106.3	105.3	108.1	107.0	106.0	108.9	107.8	106.7
9,000	106.6	105.3	104.0	107.3	105.9	104.6	107.9	106.6	105.2
12,000	106.0	104.5	103.0	106.6	105.1	103.6	107.2	105.6	104.1
15,000	105.5	103.9	102.2	106.1	104.4	102.7	106.6	104.9	103.2
18,000	105.2	103.3	101.5	105.6	103.8	101.9	106.1	104.3	102.4
24,000	104.5	102.4	100.2	104.9	102.8	100.6	105.2	103.1	100.9
30,000	103.5	101.1	98.5	103.8	101.4	98.8	104.1	101.6	99.0

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TABLE XII.—*Ballistic densities in percent of standard for low-angle fire*—Continued

Standard altitude (feet)	Station elevation in feet above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
Surface	112.0	112.0	112.0	113.0	113.0		114.0	114.0	
600	111.8	111.7	111.5	112.8	112.7		113.7	113.7	
1,500	111.5	111.2	110.7	112.4	112.1		113.4	113.0	
3,000	110.9	110.1	109.5	111.8	111.0		112.7	111.8	
4,500	110.2	109.3	108.4	111.1	110.1		111.9	110.9	
6,000	109.6	108.5	107.5	110.4	109.3		111.2	110.0	
9,000	108.6	107.2	105.9	109.3	107.9		109.9	108.5	
12,000	107.8	106.2	104.7	108.4	106.8		109.0	107.3	
15,000	107.1	105.4	103.7	107.6	105.9		108.1	106.4	
18,000	106.6	104.7	102.8	107.0	105.2		107.5	105.6	
24,000	105.6	103.5	101.3	106.0	103.9		106.4	104.3	
30,000	104.4	101.9	99.3	104.7	102.2		105.0	102.5	
Surface	115.0	115.0		116.0	116.0		117.0	117.0	
600	114.7	114.7		115.7	115.6		116.7	116.6	
1,500	114.3	114.0		115.3	114.9		116.2	115.8	
3,000	113.5	112.7		114.4	113.6		115.3	114.4	
4,500	112.7	111.7		113.5	112.5		114.4	113.3	
6,000	111.9	110.7		112.7	111.5		113.5	112.2	
9,000	110.6	109.2		111.3	109.8		111.9	110.5	
12,000	109.5	107.9		110.1	108.5		110.7	109.0	
15,000	108.7	106.9		109.2	107.4		109.7	107.9	
18,000	108.0	106.1		108.4	106.5		108.9	107.0	
24,000	106.8	104.6		107.2	105.0		107.5	105.4	
30,000	105.3	102.8		105.6	103.1		105.9	103.4	
Surface	118.0	119.0		120.0	121.0		122.0	123.0	
600	117.7	118.6		119.6	120.6		121.6	122.6	
1,500	117.2	118.1		119.1	120.0		120.9	121.9	
3,000	116.2	117.1		118.0	118.9		119.7	120.6	
4,500	115.2	116.0		116.8	117.6		118.5	119.3	
6,000	114.2	115.0		115.8	116.5		117.3	118.1	
9,000	112.6	113.3		113.9	114.6		115.3	115.9	
12,000	111.3	111.9		112.5	113.0		113.6	114.2	
15,000	110.2	110.7		111.2	111.8		112.3	112.8	
18,000	109.4	109.8		110.3	110.8		111.2	111.7	
24,000	107.9	108.3		108.7	109.1		109.4	109.8	
30,000	106.2	106.5		106.8	107.1		107.4	107.7	

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TABLE XIII.—*Meteorological equipment and supplies*

	Quantity
EQUIPMENT AND SUPPLIES	
Anemometer ML–13, or ML–58	1
Barometer ML–2 (includes W. D., Sig. C., Form No. 79) [1]	1
Barometer ML–9	1
Buzzer box ML–82 [1]	1
Case ML–48 (for barometer ML–2) [1]	1
Cock ML–56	1
Coupling ML–49	1
Head and chest set HS–17–A or HS–19 (when timing and telephone set ML–110 is not issued)	2
Hose ML–81	1
Plotting board ML–122 (includes rule ML–126), or ML–55 (includes rule ML–63)	1
Plotting board ML–120, or ML–57	1
Psychrometer ML–24	1
Scale ML–125 (per plotting board ML–122 and ML–120)	1
Scale ML–87 (per plotting board ML–55)	1
Scale ML–88 (per plotting board ML–57)	1
Support ML–29	1
Theodolite ML–47, modified for night work	1
Timing and telephone set ML–110	1
Tripod ML–78	1
Watch, wrist (ordnance) (when timing and telephone set ML–110 is not issued)	1
Wire W–110, feet	200

[1] For harbor defense meteorological stations only.

EXPENDABLE SUPPLIES

Balloons ML–50, ML–51, ML–64, ML–155, and ML–156.
Candle ML–90.
Hydrogen gas (compressed in steel cylinders).
Lantern ML–91.
Rubber bands, No. 16 or No. 18.
TM 4–240.
TM 11–420.
W. D. Sig. C. Form No. 80 (for barometer ML–2).
W. D. Sig. C. Form No. 206.
Wicks for wet-bulb thermometer.
Miscellaneous supplies (pencils, erasers, oil, etc.).

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Appendix II

ADJUSTMENT OF THEODOLITE

The instructions for setting up and orienting the theodolite (see par. 11) presuppose that the instrument itself is properly adjusted. The theodolite should be tested once a week for adjustment. The three adjustments described below should be made whenever necessary.

1. The spirit levels should be adjusted whenever the bubbles do not remain centered when the theodolite is rotated through 180° after having been leveled. The adjustment is made separately for each spirit level as follows:

a. For a theodolite with three leveling screws, turn the instrument so that one of the spirit levels is parallel to a line joining two of the leveling screws. Center the bubble in this level by turning these screws in opposite directions. Rotate the instrument 180° about the vertical axis. Bring the bubble half way to the center of the level by means of the same leveling screws. Then bring the bubble exactly to the center by turning the small screw at the end of the level vials. This operation raises or lowers the end of the spirit level as necessary. A small adjusting pin is provided with each theodolite for this purpose. Rotate the instrument through 180° and repeat the adjustment if necessary. Adjust the other level by the same method.

b. For a theodolite with four leveling screws the adjustment is made as above, except that the bubbles are leveled by diagonally opposite leveling screws.

2. To make the horizontal axis of the theodolite perpendicular to the vertical axis, set up the theodolite near a building with vertical walls. Carefully level the instrument. Sight on a point at the top of a vertical corner of the building. Clamp the horizontal motion, lower the telescope, and note a point at or near the bottom corner of the building. Turn the telescope through 180° about both the vertical and horizontal axes. Sight again on the point at the top of the building. Lower the telescope as before. If the vertical cross hair does not fall on the lower point which was previously noted, bring the vertical cross hair half way to this point by raising or lowering one end of the horizontal axis as necessary. This is done by means of two screws located above and below the horizontal axis on the opposite side from the vertical circle. Make the adjustment by tightening one screw and loosening the other. Repeat the above operations if necessary.

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3. To adjust the zero of the vertical circle, set the zero of the vernier in coincidence with the zero of the vertical circle. Sight the telescope on a vertical object and note the point on which the horizontal cross hair falls. Rotate the instrument through 180° about both the vertical and horizontal axes, and sight on the same point. Note the reading of the vertical circle. Adjust the zero of the vernier by one half of this value. Repeat this operation if necessary.

[A. G. 062.11 (8–30–41).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

E. S. ADAMS,
Major General,
The Adjutant General.

DISTRIBUTION:

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(For explanation of symbols see FM 21–6.)

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