FM 4-155

WAR DEPARTMENT

COAST ARTILLERY FIELD MANUAL

*

REFERENCE DATA

(SEACOAST ARTILLERY AND ANTIAIRCRAFT ARTILLERY)

1940

B. W. Boyes,
Lt. Col., 250th. C.A.

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(SEACOAST ARTILLERY AND ANTIAIRCRAFT ARTILLERY)

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Chief of Coast Artillery

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OFFICIAL:

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

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(SEACOAST ARTILLERY AND ANTIAIRCRAFT ARTILLERY)

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CHAPTER 3

FIRING CHARACTERISTICS AND AMMUNITION DATA, COAST ARTILLERY WEAPONS

TABLE A.—*Firing characteristics, coast artillery weapons*

Class	Caliber and type	Maximum range (yards)	Traverse (degrees)	Maximum elevation (degrees)	Rate of fire (rounds per piece per minute)
Fixed seacoast	16-inch gun	[a] 49, 100 [b] 44, 680	360	[a] 65 [b] 46	⅔
	16-inch howitzer	24, 500	360	65	⅔
	14-inch gun	25, 000	170	20	⅔
	12-inch gun (D. C. and old barbette).	18, 400	170	15	1⅓
	12-inch gun (barbette)	30, 100	360	35	1⅓
	12-inch mortar	[c] 19, 300 [d] 14, 650	360	65	1⅓
	10-inch gun	14, 700	170	12	1½
	8-inch gun	14, 200	120	12	1½
	6-inch gun (D. C.)	14, 600	170	15	4
	6-inch gun (barbette)	16, 000	360	20	5
	3-inch gun	11, 000	360	16	12
Railway	14-inch gun	48, 200	[e] 7 or 360	50	½

[a] Model 1919.
[b] Navy gun.
[c] Model 1912.
[d] Models other than 1912.
[e] The smaller traversing limit is that obtained without special construction; the larger limit is that obtained with specially constructed emplacements.

TABLE A.—*Firing characteristics, coast artillery weapons*—Continued

Class	Caliber and type	Maximum range (year)	Traverse (degrees)	Maximum elevation (degrees)	Rate of fire (rounds per piece per minute)
Railway	12-inch gun	30, 100	[e] 10 or 360	38	½
	12-inch mortar	14, 650	360	65	⅔
	8-inch gun [f]	33, 850	360	45	1⅓
155-mm	155-mm gun	17, 400	[e] 60 or 360	35	3
Antiaircraft	105-mm gun	[h] 13, 100 [g] 12, 300	360	80	15
	90-mm gun	[h] 12, 600 [g] 11, 000	360	80	17
	3-inch gun	[h] 11, 100 [g] 9, 800	360	80 and 85	25
	37-mm gun	[h] 3, 500 [g] 3, 500	360	85	120
	.50 caliber machine gun	[i] 1, 850	360	68½	500

[e] The smaller traversing limit is that obtained withot special construction; the larger limit is that obtained with specially constructed emplacements.

[f] Data is for 8-inch gun, M1. The M1918 gun has a maximum range of 23,900 yards and a maximum elevation of 42°.

[g] Maximum vertical range as limited by fuze or tracer.

[h] Maximum horizontal range as limited by fuze or tracer.

[i] Tracer range.

TABLE B.—*Ammunition data, coast artillery mobile weapons*

Class	Caliber and type	Approximate weight of complete round (packed) (pounds)	Projectile types and weights (pounds)[a]	Ammunition transport		Day of fire
				Kind	Rounds per vehicle	
Railway	8-inch gun	340	200 HE 260 AP	Railway car.	96	80
	12-inch mortar.	763	1,046 DP 700 DP 700 HE	Railway car.	48	50
	12-inch gun	920	700 HE 975 AP 1,070 AP	Railway car.	36	50
	14-inch gun	1,860	1,215 HE 1,400 AP 1,560 AP	Railway car.	24	50
155-mm	155-mm gun	148	95 HE	2½-ton truck.	35	100
Antiaircraft	90-mm gun	225 per box of 4.	21 HE	2½-ton truck.	88	250
	3-inch gun	150 per box of 4.	13 HE	2½-ton truck.	120	300
	37-mm gun	85 per box of 20.	1¼ HE	2½-ton truck.	900	1,800
	Caliber .50 machine-gun.	120 per box of 300.		1½-ton truck.	3,600	[b] 7,200 [c] 3,600

[a] Does not include some unimportant types and weights.
[b] Machine guns in machine-gun batteries.
[c] Machine guns in gun batteries.

CHAPTER 4

SYMBOLS

TABLE C.—*Symbols for seacoast artillery fire-control maps, diagrams, and structures*

Part 1.—Basic symbols.

Name	Symbol	Abbreviation
Harbor defense command post		H D C P
Groupment command post		Gpmt C P
Fort command post		Ft C P
Gun group command post		G C P
Mine group command post		M C P
Seacoast battery command post		B C P
Harbor defense observation station		H D O P
Groupment observation station		Gpmt O P
Fort observation station		Ft O P
Gun group observation station		G O P
Mine group observation station		M O P
Battery observation station		B O P

TABLE C.—*Symbols for seacoast artillery fire-control maps, diagrams, and structures*—Continued

Part 1.—Basic symbols—Continued.

Name	Symbol	Abbreviation
Emergency observation station		E O P
Antiaircraft observation post		A A O P
Battery spotting station		S O P
Separate observation station		O P
Operations and plotting room		O P R
Plotting room		P
Self-contained base range-finder station		R F
Magazine		Mg
Shell room		S Rm
Temporary or improvised fire-control structures.		Imp
Mine casemate		M C
Mine loading room		L R
Searchlight, 60-inch seacoast		S L
Searchlight, seacoast, other than 60-inch		S L

TABLE C.—*Symbols for seacoast artillery fire-control maps, diagrams, and structures*—Continued

Part 1.—Basic symbols—Continued.

Name	Symbol	Abbreviation
Antiaircraft searchlight		A A S L
Searchlight shelter		S Sh
Searchlight powerhouse		S P H
Searchlight controller booth		C B
Data booth		Data B
Watchers booth		W Bth
Meteorological station		M E T
Tide station		Td
Signal station		S S
Fire-control switchboard room		F S B
Post telephone switchboard room		P S B
Combined fire-control and post telephone switchboard room		F S B P S B
Cable terminal		C Ter
Powerhouse		P H

TABLE C.—*Symbols for seacoast artillery fire-control maps, diagrams, and structures*—Continued

Part 1.—Basic symbols—Continued.

Name	Symbol	Abbreviation
Radio powerhouse		R P H
Central powerhouse		C P H
Pumping plant		P P
Datum point		
Triangulation station		
Intersection point		
Bench mark		B M
Lighthouse		L H

Part 2.—Numbers for harbor defense installations.—a. In a harbor defense, seacoast artillery installations of each type are numbered consecutively from right to left, facing the center of the field of fire of the harbor defense. Antiaircraft installations pertaining to the harbor defense may be numbered in any convenient sequence.

b. Groupments, gun groups, mine groups, batteries, and all installations functioning directly under the harbor defense commander, such as harbor defense observation stations, searchlights, and underwater listening posts, are numbered consecutively, each type in a separate series, beginning with number 1. These numbers normally are shown as subscripts to the letter included in the appropriate symbol. Exceptions are included among the examples that follow.

Name	Symbol	Abbreviation
Harbor defense observation station		H D O P_3.
Fort observation station		Ft O P_3.
Antiaircraft observation post		A A O P 2.
Magazine or shell room		Mg 2 or SRm 2.

c. Groupment, group, and battery observation and spotting stations assigned to a unit are numbered consecutively within the unit, each type in a separate series, beginning with number 1. These numbers are shown as superscripts to the letter included in the appropriate symbol, the unit number remaining as the subscript.

Name	Symbol	Abbreviation
Groupment observation station		Gpmt$_2$ O P_2.
Gun group observation station		G_2 O P_1.
Mine group observation station		M_2 O P_1.
Battery observation station		B_1^1 O P.
Spotting station		S_3^1 O P.
Emergency observation station		E_2^1 O P.
Temporary or improvised fire-control structures		B_3^2 Imp.

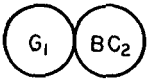
d. In certain cases it is desirable to show additional information regarding an installation, such as its size and whether fixed, portable, or mobile. Such information is placed either in the symbol or to the right thereof.

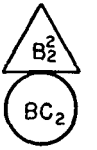
Name	Symbol	Abbreviation
60-inch seacoast searchlight; fixed, portable, or mobile.		SL 2 F (P or M).
Seacoast searchlight other than 60-inch.		SL^{36}_{3P}.
Antiaircraft searchlight; fixed, portable, or mobile.		A A S L 3 F (P or M).
Antiaircraft gun battery or composite battery, fixed or mobile.		AA No. 2 (F or M).

e. Where two stations are combined in one room, the symbols are superimposed one upon the other, and the letters representing each station are inclosed in the combined symbol.

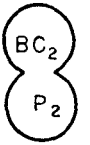
Name	Symbol	Abbreviation
Combined groupment command post and fort command post.		Gpmt Ft CP.
Combined battery observation and spotting station.		$B_1^2S_1^2O$ P.
Combined group command post and battery command post.		G_1B_2C P.
Combined battery command post and battery observation station.		B_2C P B_2^2O P.

f. Where stations are adjacent in the same structure, the symbols are tangent to each other and are arranged to show the relative location, as:





g. Where communication may be had by voice through a passage, door, window, or voice tube, the symbols are left open at the point of contact, as:



Part 3.—Communication symbols for use on harbor defense fire-control charts and diagrams.

Telephone cable (numerals indicate number of pairs and gage) ---------- 26-19
Speaking tube ---------- o o o o
Mechanical data transmission line ----------
Electrical data transmission line ---------- x x x x
Searchlight controller line ----------
Zone signal and magazine telephone line ---------- o x o x o x o x o
Firing signal line ---------- • • • • •
Time interval bell line ----------
Submarine cable (numerals indicate number of pairs and gage) ---------- 50-19

Part 4.—Abbreviations

Cable gallery	C Gal
Cable tank	C T
Cable hut (commercial cable)	C H
Coast Guard station	C G S
Engineer wharf	Engr Whf
Gasoline tank	G Tk
Guardhouse	G H
Latrine	L

Part 4.—Abbreviations—Continued.

Lighthouse wharf	L H Whf
Mine boathouse	M B H
Mine derrick	M Drk
Mine tramway	M Tmy
Mine wharf	M Whf
Ordnance machine shop	O M S
Private wharf	Pvt Whf
Radio (commercial station)	Rad
Railway wharf	Ry Whf
Saluting battery	Sl B
Service dynamite room	S D R
Steamship wharf	S S Whf
Quartermaster wharf	Q M Whf
Superseded (for abandoned buildings, etc.)	24 s
Temporary (for all uses except fire-control structures)	19 t
Sunset gun	S G
Tide gage	T G
Torpedo storehouse	T S
Tower	Tw
Water tank	W Tk
Weather bureau	W B

TABLE D.—*Greek Alphabet*

Caps	Lower case	Greek name	Caps	Lower case	Greek name
A	α	Alpha.	N	ν	Nu.
B	β	Beta.	Ξ	ξ	Xi.
Γ	γ	Gamma.	O	o	Omicron.
Δ	δ	Delta.	Π	π	Pi.
E	ϵ	Epsilon.	P	ρ	Rho.
Z	ζ	Zeta.	Σ	σ	Sigma.
H	η	Eta.	T	τ	Tau.
Θ	θ	Theta.	Υ	υ	Upsilon.
I	ι	Iota.	Φ	ϕ	Phi.
K	κ	Kappa.	X	χ	Chi.
Λ	λ	Lambda.	Ψ	ψ	Psi.
M	μ	Mu.	Ω	ω	Omega.

TABLE E.—*Symbols used in antiaircraft artillery*

a. The prescribed symbols used in antiaircraft artillery are given below, arranged in alphabetical order. *For definitions of the terms* indicated, see chapter 5.

b. Both English and Greek letters are used as symbols and as prefixes to symbols and the former are also used as subscripts to symbols. Numbers are used as subscripts only. The complete Greek alphabet is given in table D.

c. The prefix *d* is used with a symbol to indicate a correction to the element of data. The prefix Δ (delta) is used to indicate a change in the element of data.

d. The subscripts *o* and *p* are used with *T* to indicate, respectively, the position at the instant of firing (present position), and the predicted (future) position. These subscripts are used similarly with *A*, *a*, *ε*, *D*, *F*, *H*, *R*, and *t* to indicate the particular element corresponding to these two positions of the target. The other subscripts used have, in general, a special meaning, depending on the symbol with which they are used.

Symbol	Pronounced	Term
A	*A*	Azimuth.
A_f	*A* sub *f*	Firing azimuth.
A_o	*A* sub *o*	Azimuth of target at instant of firing (present position).
A_p	*A* sub *p*	Azimuth of target at its predicted (future) position.
A_w	*A* sub *w*	Wind azimuth.
α	Alpha	Angle of approach.
α_c	Alpha sub *c*	Complement of the angel of approach (α).
α_o	Alpha sub *o*	Angle of approach of target at instant of firing (present position).
α_p	Alpha sub *p*	Angle of approach of target at its predicted (future) position.
β	Beta	Wind-fire angle.
γ	Gamma	Angle of dive; that is, angle between course of target and the horizontal.
CB	*CB*	Center of burst.
D	*D*	Slant range.
$D_{m\,p}$	*D* sub *m-p*	Slant range to target at the midpoint of the course.
D_m	*D* sub *m*	Minimum slant range.

TABLE E.—*Symbols used in antiaircraft artillery*—Continued

Symbol	Pronounced	Term
D_o	*D* sub *o*	Slant range of target at instant of firing (present position).
D_p	*D* sub *p*	Slant range of target at its predicted (future) position.
ΔA	Delta *A*	Change in azimuth.
$\Delta\epsilon$	Delta epsilon	Change in angular height.
ΔH	Delta *H*	Change in altitude.
ΔR	Delta *R*	Change in horizontal range.
ΔA_w	Delta *A* sub *w*	Change in azimuth due to wind.
ΔX	Delta *X*	Travel of the target in E-W direction during the time of flight.
ΔY	Delta *Y*	Travel of the target in N-S direction during time of flight.
dH	*dH*	Altitude correction.
$d\phi$	*d* phi	Quadrant elevation correction.
dt	*dt*	Time of flight correction.
dV	*dV*	Muzzle velocity correction.
δ	Delta	Lateral deflection angle.
δ_1	Delta sub 1	Principal lateral deflection angle.
δ_2	Delta sub 2	Lateral pointing correction.
δ_{2a}	Delta sub 2*a*	Lateral adjustment correction.
δ_{2d}	Delta sub 2*d*	Lateral pointing correction due to drift.
δ_{2w}	Delta sub 2*w*	Lateral pointing correction due to cross wind.
δ_b	Delta sub *b*	Lateral tracer lead.
δL	Delta sub *L*	Lateral lead. This includes the lead necessary for the travel of the target, during the time of flight, plus or minus corrections for wind, drift, and lateral spot corrections.
ϵ	Epsilon	Angular height.
ϵ_o	Epsilon sub *o*	Angular height of target at instant of firing (present position).
ϵ_p	Epsilon sub *p*	Angular height of target at its predicted (future) position.
F	*F*	Fuze range.
H	*H*	Altitude.
H_m	*H* sub *m*	Altitude of the target at the mid-point of the course.
H_o	*H* sub *o*	Altitude of the target at instant of firing (present position).
H_p	*H* sub *p*	Altitude of the target at predicted (future) position.
L	*L*	Distance measured from the midpoint (T_m) of crossing course to a point on the course. Positive if measured in the direction of flight.
L_o	*L* sub *o*	Distance from midpoint (T_m) to the target at instant of firing (present) position.

TABLE E.—*Symbols used in antiaircraft artillery*—Continued

Symbol	Pronounced	Term
L_p	*L* sub *p*	Distance from midpoint (T_m) to the target at predicted (future) position.
LD	*LD*	Lateral deflection setting.
$\eta\mu$	Mils	Mils.
MV	*MV*	Muzzle velocity.
O_1	*O*-one	The observation station at the battery.
O_2	*O*-two	The flank observation station.
PE	*PE*	Probable error.
π	Pi	3.1416.
ϕ	Phi	Quadrant elevation.
ϕ_s	Phi sub *s*	Superelevation under firing-table conditions.
ϕ_{sa}	Phi sub *sa*	Superelevation under conditions actually existing.
R	*R*	Horizontal range.
R_1	*R* sub 1	Horizontal range to target at instant of observation.
R_m	*R* sub *m*	Horizontal range to target at midpoint of course.
R_o	*R* sub *o*	Horizontal range to target at instant of firing (present) position.
R_p	*R* sub *p*	Horizontal range to target at predicted (future) position.
S_a	*S* sub *a*	Air speed of target.
S_g	*S* sub *g*	Ground speed of target.
Σ	Sigma	Angular velocity.
Σ_a	Sigma sub *a*	Angular velocity in azimuth.
Σ_e	Sigma sub *e*	Angular velocity in angular height.
σ	Sigma	Vertical deflection angle.
σ_1	Sigma sub 1	Principal vertical deflection angle.
σ_2	Sigma sub 2	Vertical pointing correction.
σ_{2a}	Sigma sub 2*a*	Vertical adjustment correction.
σ_{2d}	Sigma sub 2*d*	Vertical pointing correction due to density.
σ_{2V}	Sigma sub 2*V*	Vertical pointing correction due to muzzle velocity.
σ_{2w}	Sigma sub 2*w*	Vertical pointing correction due to range wind.
σ_L	Sigma sub *L*	Vertical lead. This includes the lead necessary for travel of target, during the time of flight, plus superelevation, corrections for wind and density effects, and vertical spot corrections.
T	*T*	The position of the target.
T_m	*T* sub *m*	Midpoint. Point on crossing course where the angle of approach (α) equals 90°.
T_o	*T* sub *o*	The position of the target at instant of firing (present position).
T_p	*T* sub *p*	The predicted (future) position of the target.
t	*t*	Time of flight.
t_d	*t* sub *d*	Dead time.

TABLE E.—*Symbols used in antiaircraft artillery*—Continued

Symbol	Pronounced	Term
t_o	*t* sub *o*	Time of flight to the present position of the target.
t_p	*t* sub *p*	Time of flight to the future position of the target.
TSP	*TSP*	Trial shot point.
VD	*VD*	Vertical deflection setting.
W	*W*	Velocity of the ballistic wind.
X_o	*X* sub o	E-W component of the horizontal range to target at instant of firing (present position).
X_p	*X* sub *p*	E-W component of the horizontal range to target at predicted (future) position.
Y_o	*Y* sub o	N-S component of the horizontal range to target at instant of firing (present position).
Y_p	*Y* sub *p*	N-S component of the horizontal range to target at predicted (future) position.

CHAPTER 5

GLOSSARY OF TERMS

NOTE.—Certain of the following terms and definitions apply only to antiaircraft artillery and are designated (AA). Terms and definitions applying only to seacoast artillery are designated (SCA). For antiaircraft artillery symbols, see table E.

Absolute deviation.—See Deviation.

Accidental errors.—Those errors which are nonsystematic in nature and which in artillery fire cause the dispersion of shots about the center of impact. They may arise from such sources as the variation from round to round in the operation of instruments, in muzzle velocity, in the weight and shape of projectiles, and in the action of the gun and carriage.

Accuracy of fire.—Accuracy of fire is determined by dispersion and is measured by the closeness of the grouping of points of impact or burst about their center of impact.

Accuracy of practice.—Accuracy of practice is measured by the distance of the center of impact from the center of the target; also known as accuracy of the shoot.

Acoustic corrections (AA).—Corrections to data for nonstandard atmospheric conditions and sound lag, applied on the acoustic corrector.

Acoustic corrector (AA).—An instrument for determining and applying angular corrections to the azimuth and elevation data, as obtained by the sound locator, for the travel of the airplane during the interval required by the sound wave to travel from its source to the sound locator and also for the deviating effects on the sound waves of varying atmospheric conditions.

Acoustic wind (AA).—A fictitious wind constant in velocity and direction which is assumed to have the same effect on a sound wave as the winds actually encountered.

Adjusted range or adjusted range correction.—That range or range correction obtained or proved by actual firing which places the center of impact at or near the target.

Adjusting point.—The particular point on which fire is adjusted.

Adjustment corrections.—*See* Arbitrary corrections; *see also* Spot.

Adjustment of fire.—The process of determining and applying corrections to firing data to bring the center of impact or of burst, or the cone of fire of automatic weapons, to the adjusting point and to keep it there.

Aerial observation (SCA).—Observation of fire from aircraft.

Aerial sound ranging (AA).—The process of locating aircraft by means of the sounds emitted.

Aiming.—The operation of pointing the gun in range or direction or in both range and direction by means of the sight.

Aiming point.—The point on which the gun pointer sights in pointing the gun.

Air speed (AA).—The speed of an airplane with reference to the air through which it is flying. The air speed differs from the ground speed by the effect of wind on the movement of the airplane.

Airplane defense area.—As referred to in antiaircraft defense, a definitely defined area, beyond the range of friendly antiaircraft artillery guns, which is protected by pursuit aviation operating alone during daylight hours and in conjunction with antiaircraft artillery searchlights during hours of darkness.

Altimeter (AA).—An instrument used in determining the altitude of the target. Two such instruments are required for this purpose.

Altitude (AA).—The vertical distance to a point in space from a horizontal reference plane, usually the horizontal plane containing the battery.

Altitude (SCA).—The vertical distance above or below sea level (mean low water) or other datum level. Also called height of site.

Angle of approach.—The acute horizontal angle between the plane of position and the vertical plane containing the course of the target.

Angle of departure.—The angle between the line of departure and the line of position.

Angle of depression.—The angular depression of the line of position below the horizontal plane.

Angle of elevation (or elevation).—The angle between the line of elevation and the line of position.

Angle of fall.—The angle between the line of fall and the base of the trajectory.

Angle of impact.—The acute angle between the line of impact and the plane tangent to the surface of the ground (or other object) at the point of impact.

Angle of incidence.—The acute angle between the line of impact and the normal to the surface of the ground (or other object) at the point of impact. It is the complement of the *angle of impact.*

Angle of jump.—The difference between the angle of departure and the angle of elevation. Its component in the vertical plane is called the *vertical jump* and its component in the horizontal plane is called the *lateral jump.*

Angle of obliquity.—*See* Angle of incidence.

Angle of site.—The angle between the line of site (position) and the base of the trajectory.

Angular height.—The vertical angle between the line of position and the horizontal.

Angular travel error.—The error which is introduced into a predicted angle obtained by multiplying an instantaneous angular velocity by a time of flight.

Angular travel method (AA).—A method of determining firing data based upon the rate of angular travel of the target in azimuth and elevation.

Angular unit method (AA).—A method of adjusting antiaircraft artillery gunfire, in which range deviations in mils obtained by a distant observer are converted into altitude corrections in yards, for application at the data computor.

Angular velocity.—The rate of change of direction expressed in angular measure. In antiaircraft artillery practice, angular velocity is measured in its two components, the vertical angular velocity or rate of change of angular height, and the lateral angular velocity or rate of change of azimuth.

Antiaircraft artillery.—Antiaircraft artillery comprises those coast artillery organizations whose primary mission is the

ground defense of troops and important facilities against activities of enemy aviation.

Antiaircraft artillery area defense.—A thoroughly organized and coordinated antiaircraft artillery defense of a definite area, which is protected by the mutually supporting fires of antiaircraft artillery guns and automatic weapons. *See also* Forward area and Rear area.

Antiaircraft artillery defense.—That class of defense provided by antiaircraft artillery against attack from the air.

Antiaircraft artillery gun area.—An area within which all localities are protected by the fire of antiaircraft artillery guns. *See also* Incidental protection and Special protection.

Antiaircraft defense.—That class of defense provided by the coordinated employment of air and ground forces against attack from the air. It includes passive means of defense.

Approximate lateral deflection angle (AA).—*See* Lateral deflection angle.

Approximate vertical deflection angle (AA).—*See* Vertical deflection angle.

Arbitrary corrections.—Corrections to firing or sound locator data which are applied to correct for conditions or observed deviations, after all known deviating causes have been corrected for.

Area defense.—*See* Antiaircraft artillery area defense.

Armament error.—The divergence, stripped of all personnel errors and adjustment corrections, of an impact or burst from the center of impact of a series similarly stripped.

Ascending branch.—That portion of the trajectory between the origin and the summit.

Automatic weapon defense.—The particular class of defense provided by antiaircraft artillery automatic weapons.

Axial observation (SCA).—Observation of fire from a point on or near the gun–target line. Observation is said to be axial when the observing angle is 5° or less.

Axis of bore.—The center line of the bore of the gun.

Axis of trunnions.—The axis about which a cannon is rotated in elevation.

Azimuth.—The horizontal angle, measured in a clockwise direction, from a selected reference line passing through the

position of the observer, to the horizontal projection of the line of sight from the observer to the objective.

Azimuth difference.—The difference between the two azimuths of a point as measured from two other points. Also called parallax.

Backlash.—The lost motion or "play" in a mechanical system.

Ballistic coefficient.—The numerical measure of the ability of a projectile to overcome air resistance and maintain its velocity.

Ballistic density.—A fictitious constant density of the atmosphere which would have the same total effect on the projectile during its flight as the varying densities actually encountered.

Ballistic wind.—A fictitious wind, constant in velocity and direction, which would have the same total effect on the projectile during its flight as the true winds actually encountered.

Ballistics.—That branch of applied mechanics which treats of the motion of projectiles. It is divided into two main branches—*interior ballistics* and *exterior ballistics*. The former is concerned with the motion of the projectile while in the gun, and the latter treats of the motion of the projectile after it has left the gun.

Barrage fire.—Fire having for its purpose the placing of a curtain or barrier of fire, executed on predetermined firing data, across the probable course of the enemy.

Base line.—A line of known length and direction between two observation or spotting stations, the positions of which with respect to the battery are known. The base line is called *right-handed* or *left-handed*, depending on whether the secondary station is to the right or left of the primary from the point of view of a person facing the field of fire.

Base of trajectory.—The straight line joining the origin and the level point.

Base piece.—The gun selected after calibration fire, the center of burst or impact of which is taken as the reference point in determining calibration corrections for the remaining guns of the battery. No calibration corrections are applied to the base piece.

Base ring.—The metal ring which is bolted to the concrete of an emplacement and which supports the weight of the cannon and carriage.

Battery commander's telescope (AA).—An instrument containing two collimated optical systems, the first being designed to enable an operator to follow a target, and the second to afford the battery commander or his observer an opportunity to study the target at convenient times. The second optical system is provided with suitable mil scales for observation of fire.

Battle chart.—A chart used in group and higher commands showing the water area covered by the armament of their respective commands.

Bilateral observation.—Observation of fire from two observation stations.

Biting angle (SCA).—The maximum angle of obliquity at which penetration of armor is secured.

Bomb-release line (AA).—An imaginary line drawn around a defended area over which a bomber, traveling toward it at a constant speed and altitude, should release its first bomb to have it strike the nearest edge of the defended area.

Bore rest.—*See* Clinometer rest.

Bore sighting.—The process by which the axis of the bore and the line of sight are made parallel, or are made to converge on a point.

Bracket.—The difference between two ranges or two adjustment corrections, one of which indicates a center of impact which is over the target and the other a center of impact which is short of the target. The term is also used in a similar manner with reference to direction.

Bracketing correction.—An adjustment correction which gives an equal number of overs and shorts.

Bracketing elevation.—An elevation which gives an equal number of overs and shorts.

Bracketing method of adjustment (SCA).—The method of fire adjustment used when the sense only and not the magnitude of the deviation is known. (*See also* Modified bracketing method.)

Bracketing salvo.—A salvo in which the number of impacts sensed short is equal to the number of impacts sensed over.

Burst fire (problem) (AA).—*See* Verification fire.

Calibration.—*See* Calibration fire.

Calibration corrections.—Corrections which are applied on the guns as a result of calibration fire.

Calibration fire.—Preparatory fire having for its purpose the determination of the separate corrections to be applied to the individual guns of a battery in order to cause all the guns to hit the same point, or the bursts or impacts to assume a desired pattern.

Calibration point.—A point at which calibration fire is conducted.

Cant.—The angle made with the horizontal by the axis of the trunnions.

Case I pointing.—*See* Pointing.

Case II pointing.—*See* Pointing.

Case III pointing.—*See* Pointing.

Center of burst (AA).—The mean point in space of a particular series of bursts.

Center of dispersion.—*See* Dispersion.

Center of impact (SCA).—The mean position of the points of impact of a particular series of shots fired with the same elevation (or with the same adjustment correction).

Central control (AA).—A method of fire control for automatic weapons in which leads and pointing corrections are controlled from a central point rather than by the individual gunner.

Chronograph.—An instrument for measuring and recording graphically short intervals of time. More specifically, an instrument for determining the velocity of projectiles.

Clinometer.—An instrument for measuring accurately vertical angles; for example, the inclination of the axis of the bore to the horizontal.

Clinometer rest.—A device inserted in the bore of the gun for supporting a clinometer. It is also called a *bore rest.*

Clinometering.—The process of adjusting the elevation indicating device on a gun using a clinometer so that it indi-

cates accurately the quadrant elevation of the gun when elevated to any position.

Close formation.—The formation taken by motor columns when distances between vehicles are decreased, such as when going through towns or cities.

Coefficient of form.—A factor introduced into the ballistic coefficient to make its value conform to results determined by firing.

Combat zone.—That portion of the forward area of the theater of operations required for active operations and for the establishment of the necessary supply and evacuation facilities for the troops therein.

Communications zone.—That portion of the theater of operations in rear of the combat zone that contains the principal establishments of supply and evacuation, lines of communication, and other agencies required for the continuous service of the forces in the theater of operations.

Comparator (AA).—An instrument for indicating the relation between the data determined by the sound locator and the data indicated by the pointing of the searchlight.

Conduct of fire.—The employment of technical means to place accurate fire on a target.

Continuous fire.—Fire conducted at the normal rate, without interruption for the application of adjustment corrections or for other causes.

Continuously pointed fire.—Fire in which the fire-control devices are directed on the target and the data vary continuously with the position of the target.

Contradiction.—A contradiction is obtained when two shots, fired with the same elevation or with the same adjustment correction, give impacts of opposite sense. A contradiction may also be obtained in direction.

Control station.—A device which permits the searchlight to be pointed in elevation and azimuth from a distant point. The station consists of a distant electric controller and a comparator or zero reader mounted on a tripod.

Controller.—*See* Distant electric control.

Corrected azimuth.—The azimuth from the directing point to the target corrected for all known variations from those conditions assumed as standard in the construction of firing tables.

Corrected deflection.—The deflection corrected for all known variations from those conditions assumed as standard in the construction of firing tables.

Corrected elevation.—The firing table elevation corresponding to the corrected range.

Corrected range.—The range corrected for all known variations in conditions from those assumed as standard in the construction of firing tables. It is the computed range at which the piece should be set.

Corrector setting (AA).—The setting applied on the fuze setter in order to set the fuze at a different value from that determined by the normal operation of the data computor.

Critical zone (AA).—The zone immediately beyond the bomb-release line of a defended area equal in width to the distance traveled by an airplane during the time necessary to operate the bomb sight.

Danger space (SCA).—That portion of the range within which a target of given dimensions would be hit by a projectile with a given angle of fall. It is the area indicated by projecting the target on to the surface of the earth or water, along lines parallel to the line of fall of the projectile.

Data computor.—A predicting instrument used to determine the firing data pertaining to the future position of the target. There are three types of data computors: The *ballistic,* the *nonballistic,* and the *semiballistic.*

Ballistic data computor.—A data computor which contains means for computing corrections to firing data due to nonstandard ballistic conditions; namely, wind, atmospheric density, and muzzle velocity.

Nonballistic data computor.—A data computor which has no means for computing corrections due to variations in ballistic conditions.

Semiballistic data computor.—A data computor which contains means for computing corrections to firing data due to some but not all nonstandard ballistic conditions; namely, wind and for certain fixed variations in muzzle velocity, but no means for computing corrections due to density variations.

Datum or datum level.—A spherical surface which represents mean sea level or other established reference level from which altitudes are measured.

Datum point.—A fixed point, the azimuth and range of which have been accurately determined from one or more observing stations or other positions.

Day of fire.—An arbitrary unit of measure of ammunition supply expressed in rounds per weapon. It is based on the average expenditure by large commands in one day of combat.

Day of supply.—Term used to express estimated average expenditure per day in campaign of the various items of supply except ammunition.

Dead areas.—Areas that cannot be reached by fire. These may be caused by masks in front of the battery as well as by obstructions in the descending path of the projectile.

Dead time.—The time interval represented by the travel of the target from its position at observation to its present position. It is the time necessary to compute and utilize an element of the firing data.

Defilade.—The vertical distance by which a position is concealed from enemy observation. If the smoke and flash of firing are also concealed, the battery is said to have smoke and flash defilade.

Deflection.—The setting on the deflection scale of a sight such that when the line of sight is on the aiming point the piece is pointed in direction.

Deliberate fire.—Fire which is conducted at a rate intentionally less than the normal rate of fire of the battery, in order that adjustment corrections may be applied between series, or for tactical reasons.

Density.—Density of the air measures the mass that must be displaced by the projectile. It varies with the altitude, decreasing as the altitude increases. In practice the density used is the *ballistic* density.

Density of loading.—The term employed to represent the density of the contents of the powder chamber. It is the ratio of the weight of the powder charge to the weight of a volume of distilled water at 39.2° F. which will fill the powder chamber.

Descending branch.—That part of the trajectory described by the projectile after it passes the summit.

Developed armament probable error (D. A. P. E.).—The probable armament error as computed from a finite series of shots. It is the average armament error of a particular series of shots multiplied by 0.845.

Deviation (AA).—The angular or linear displacement of a point of burst, or a center of burst, from the target or the adjusting point. Deviations are normally measured in mils above or below (*vertical* deviation) and right or left (*lateral* deviation) of the line of position and over or short (*range* deviation) of the target. In antiaircraft artillery automatic-weapon fire the deviations are measured in angular units from the center of the cone of fire, as indicated by the tracers, to the target.

Deviation (SCA).—The distance of a point of impact, or center of impact of a series of shots, from the center of the target. If a set of axes is drawn through the target, the *Y* axis being parallel to the line of position and the *X* axis perpendicular to the *Y* axis, then the *Y* coordinate of the impact is called its *longitudinal deviation* and the *X* coordinate is called its *lateral deviation*. The shortest distance from the center of the target to the point of impact is called the *absolute deviation*.

Difference chart.—A graphic device by means of which the range and azimuth of a target from a gun or station are obtained when the range and azimuth from some other gun or station are known.

Differential effects.—The effects upon the elements of the trajectory due to variations from firing table conditions.

Direct fire.—Fire conducted with direct pointing.

Direct pointing.—Pointing a piece in direction or in both range and direction by means of a sight directed at the target.

Directing point.—A point in or near a battery for which the initial firing data are computed. If a gun of the battery is the directing point, it is called the *base piece* or *directing gun*.

Director.—*See* Data computor.

Directrix.—The center line of the field of fire of a gun.

Dispersion.—The scattering of shots fired with the same data. The area over which the shots are scattered is called the *zone of dispersion.* The center of that area is called the *center of dispersion.*

Dispersion diagram.—A diagram made up by superimposing the dispersion ladder for direction on the dispersion ladder for range and indicating in each resulting rectangle the percentage of shots expected to fall therein.

Dispersion ladder.—A diagram made up of eight successive zones, each equal in width to one probable error. The center of dispersion is on the line between the two central zones and in each zone is indicated the percentage of shots expected to fall therein.

Displacement.—The displacement of one point from another is the distance between these points. *Gun displacement* is the horizontal distance in yards from the pintle center of the gun to the directing point or directing gun of the battery.

Distant electric control.—A system for the control of the pointing of searchlights from a distance. The control consists of the controller and the necessary motors or receivers at the searchlight.

Distributing point.—A location at which supplies are issued to unit trains.

Drift.—The divergence of a projectile from the plane of departure due to the rotation of the projectile and the resistance of the air. It may be expressed either in linear or angular units. The drift listed in firing tables includes lateral jump.

Drop.—The vertical distance from a point on the trajectory to the line of elevation.

Elements of the trajectory.—The phrase applied to the various features of the trajectory.

Elevation.—*See* Angle of elevation and Quadrant elevation.

Elevation table.—A table of ranges with corresponding quadrant elevations for a particular gun and mount of a particular height of site. The quadrant elevations tabulated in the elevation table are firing-table elevations corrected for height of site.

Errors.—Divergences of points of impact or burst from the center of impact or burst. Practically, they are measured from the apparent center of impact or burst of a given series and when so measured are called *apparent errors*, as differentiated from *true errors* which would be measured from the true center of impact or burst.

Estimated data.—Firing data which are determined by estimation.

Exterior ballistics.—*See* Ballistics.

Field of fire.—That portion of the terrain or water area covered by the fire of a gun or battery.

Fifty percent zone.—The zone extending one probable error on each side of the center of impact within which 50 percent of the shots are expected to fall.

Fire control.—The exercise of conduct of fire and fire direction.

Fire direction.—The exercise of the tactical command of one or more units in the selection of objectives and in the concentration or distribution of fire thereon at the appropriate times.

Fire for effect.—Any fire conducted against a hostile target.

Firing azimuth.—The azimuth at which the gun is laid for firing.

Firing data.—All data necessary for firing a gun at a given objective.

Firing elevation.—The firing table elevation corresponding to the firing range.

Firing range.—The corrected range further corrected for an individual cannon.

Firing table.—A collection of data, chiefly in tabular form, intended to furnish the ballistic information necessary for conducting the fire of a particular model of gun with specified ammunition.

Flank observation.—A case of unilateral observation of fire from a point on or nearly on the flank of the target. The term is used when the observing angle is greater than 75°.

Flash defilade.—*See* Defilade.

Fork (AA).—The difference in altitude or fuze range required to change the center of burst by four probable errors in range. In antiaircraft artillery fire a change in

altitude of 4 percent is considered equivalent to a change of one fork in slant range.

Fork (SCA).—The difference in range or elevation or direction required to change the center of impact by four probable errors.

Forward area.—That portion of a theater of operations in which attack by ground forces is probable. It embraces primarily the area covered by the combat zone.

Future angular height (azimuth, and so forth) *(AA).*—A term denoting the element of data pertaining to the *future* position of the target.

Fuze.—A device which controls the time of burst of a projectile.

Fuze error (AA).—The variation in fuze range from standard as determined for a particular lot of ammunition.

Fuze range (AA).—The fuze setting necessary to produce a burst at a given point in space.

Fuze range disk (AA).—A disk, a part of the M1917 and M1918 gun sights, containing curves graduated in terms of fuze range, by means of which the amount of superelevation for a given set of conditions is automatically determined and applied to the sighting system of the gun.

Fuze range pattern method (AA).—A method of adjusting antiaircraft artillery gunfire in which the observer uses the length of the pattern of bursts (the fuze range pattern) as a unit of measure in estimating the amount of the range deviations.

Grid azimuth.—Azimuth measured from grid north or south.

Ground speed of the target (AA).—The speed or linear velocity of the target with reference to the ground. The ground speed of the target is its air speed plus or minus the effect of the wind.

Gun area (AA).—*See* Antiaircraft artillery gun area.

Gun defense (AA).—The particular class of defense provided by antiaircraft artillery guns.

Gun difference.—The difference, due to displacement, between the range from a gun to the target and the range from the directing point to the target.

Gun displacement.—*See* Displacement.

Gunner's quadrant.—An instrument used on the quadrant seat of a cannon to measure the vertical angle between the axis of the bore and the horizontal.

Gunnery.—The practice of firing guns. It includes a study of the flight of the projectile and of the technical considerations involved in the conduct of fire.

Height finder (AA).—A self-contained instrument used to determine altitudes. There are two general types of height finders; *coincidence* and *stereoscopic.* The latter normally is used in antiaircraft artillery.

Height of site.—The altitude above or below the assumed datum level.

High-angle fire (SCA).—Fire in which ranges decrease with increase in angles of elevation.

Hit.—An impact actually on the target.

Hitting area.—An area, symmetrical with respect to the true center of impact, such that if a target is included therein, there will be a reasonable probability of hitting.

Horizontal base system.—A system of position finding in which the target is located from two observing stations.

Horizontal range (AA).—The length of the base of the vertical right triangle in space, the vertical side of which is altitude and the hypotenuse of which is the line of position.

Hundred percent rectangle.—A rectangle whose length is eight probable errors in range, and whose breadth is eight probable errors in direction. Its center is the center of dispersion.

Incidental protection (AA).—The protection received by an element or establishment as a result of its being located within the effective radius of action of antiaircraft weapons, disposed for the special protection of nearby elements or establishments.

Indirect fire.—Fire conducted with indirect pointing.

Indirect pointing.—Pointing a piece in direction by the use of a sight and an aiming point other than the target, or by the azimuth circle on the carriage, and in elevation by range drum or quadrant. *See* Pointing, Case III.

Individual control (AA).—A method of fire control employed with automatic weapons in which fire is controlled by the individual gunner.

Initial point.—An easily recognized terrain feature, such as a road junction located at or near the place where the various groups of trucks come together, or form column, when passing out of or entering an area.

Initial velocity.—*See* Muzzle velocity.

Interior ballistics.—*See* Ballistics.

Interrupted fire (AA).—Fire at a particular target in short series of bursts, the maximum rate in each series being maintained by all guns.

Jump.—The angle between the axis of the bore when the piece is laid and the line of departure. Its component in a vertical plane is called *vertical jump* and its component in a horizontal plane is called *lateral jump.* In firing tables, quadrant elevation includes the effect of vertical jump and drift includes the effect of lateral jump.

Lateral adjustment correction (AA).—*See* Lateral deflection angle.

Lateral deflection angle (AA).—The horizontal angle representing the difference between the azimuth of the target at the instant of firing and the azimuth at which the gun must be pointed in order to hit the target. It is the algebraic sum of the principal lateral deflection angle and the lateral pointing correction.

Approximate lateral deflection angle.—An approximation of the principal lateral deflection angle obtained by multiplying an instantaneous lateral angular velocity by a time of flight.

Lateral pointing correction.—That part of the lateral deflection angle due to causes other than the travel of the target, such as wind, drift, and lateral adjustment correction.

Principal lateral deflection angle.—That part of the lateral deflection angle due to the change in the azimuth of the target during the time of flight.

Lateral deflection setting (AA).—The setting on the lateral deflection scale of the sighting mechanism of the gun, corresponding to the lateral deflection angle.

Lateral deviation.—*See* Deviation.

Lateral jump.—*See* Jump.

Lateral lead (AA).—The horizontal angle by which the gun must be traversed to the right or left of the line of position for the trajectory to pass through the target. It is equal to the algebraic sum of the principal lateral deflection and the lateral pointing correction.

Lateral pointing correction (AA).—*See* Lateral deflection angle.

Laying.—The operation of pointing the gun in elevation or direction or in both elevation and direction without the use of a sight.

Lead.—*See* Lateral lead and Vertical lead.

Level point.—A point on the descending branch of the trajectory at the same altitude as the muzzle of the gun. It is the same as the *point of fall.*

Leveling.—The process of adjusting the gun and mount or an instrument so that all vertical or horizontal angles may be measured in true horizontal or vertical planes.

Line of collimation.—The line from the center of the objective lens of a telescope through and perpendicular to the axis of vertical rotation.

Line of departure.—The prolongation of the axis of the bore as the projectile leaves the muzzle of the gun. It is the tangent to the trajectory at the origin.

Line of elevation.—The prolongation of the axis of the bore when the piece is laid.

Line of fall.—The tangent to the trajectory at the level point.

Line of impact.—The tangent to the trajectory at the point of impact.

Line of position.—The line of position of a point is the straight line connecting the origin with that point. Also called *line of site.* The point of origin is usually the gun or a position-finding instrument. Thus, corresponding to the three positions of the target there are the line of position at observation, the line of present position, and the line of future position.

Line of sight.—The line of vision; the optical axis of an observing instrument.

Line of site.—*See* Line of position.

Linear speed method (AA).—A method of determining firing data based upon linear speed of the target.

Longitudinal deviation.—*See* Deviation.

Low-angle fire (SCA).—Fire in which ranges increase with increase in angles of elevation.

Machine-gun defense.—The particular class of defense provided by antiaircraft artillery machine guns.

Magnitude method of adjustment (SCA).—A method of adjustment used when the actual magnitudes and senses of the deviations are known.

Manning table.—A table showing the assignment of the personnel of an organization to duties.

Map range.—The range from the piece to any point as scaled or computed from a map.

March order.—The order for placing the battery or unit in readiness to move.

Mask.—Any natural or artificial feature of or on the terrain which affords shelter from view.

Maximum ordinate.—The difference in altitude between the origin and the highest point of the trajectory.

Mean error.—The arithmetical average of errors of a series of shots.

Meteorological datum plane.—The plane assumed as a basis or starting point for the data furnished to the artillery concerning atmospheric conditions. Its altitude is that of the meteorological station.

Mil.—One sixty-four-hundredth part of a circle. For practical purposes the arc which subtends a mil at the center of a circle is equal in length to one one-thousandth of the radius.

Mistakes.—Those personnel errors which may be avoided by proper care.

Modified bracketing method (AA).—A method of adjusting antiaircraft artillery gunfire, used when stereoscopic spotting is employed at the gun position. The fork (4 percent of the altitude) is the unit of adjustment.

Muzzle velocity.—The velocity of the projectile at the origin of the trajectory. Also called initial velocity.

Muzzle velocity line (AA).—A line passing through a point in space which is the locus of bursts fired at that point when only the muzzle velocity varies from normal. It is constructed from data contained in the firing tables

giving, for any particular combination of quadrant elevation and fuze setting, the effect upon the altitude and horizontal range of the burst due to a change of 100 foot-seconds in the muzzle velocity.

Nonsystematic errors.—*See* Accidental errors.

Normal.—Geometrically the term means perpendicular to. When used in connection with reference scales of instruments the normal setting is that reference scale setting which corresponds with a true setting of zero.

Objective plane (SCA).—The plane tangent to the ground or other material object at the point of impact.

Observation of fire.—The process of observing artillery fire. *See also* Spotting.

Observed angular height (azimuth, and so forth).—A term denoting the element of data pertaining to the position of the target at instant of observation.

Observing interval.—The time interval between two successive observations made on a moving target during tracking.

Observing line.—The line joining the observer and the observing point.

Observing point.—The point on which the observer sights.

Observing sector.—The sector between the lines to the right and left limiting the area visible to the observer, or limiting the area assigned for surveillance.

Open formation.—The formation taken by motor columns in open country (increased distances between vehicles).

Organic antiaircraft defense.—The antiaircraft defense provided by the organic weapons of units other than antiaircraft artillery.

Orientation.—The determination of the horizontal and vertical location of points and the establishment of orienting lines, or lines of known direction. The process of adjusting the azimuth circles of guns or instruments, or both, so that they will read correct azimuths when pointed in any direction.

Orienting line.—A line of known direction, over one point of which it is possible to place an angle-measuring instrument.

Origin of trajectory.—The center of the muzzle of the gun at the instant of departure.

Parallax.—The angle subtended at a certain point by a line connecting two other points.

Pattern.—The distribution of the points of burst or impact of a salvo. Also the difference in range between the point of impact with the longest range and the point of impact with the shortest range, excluding wild shots. The pattern of a salvo in direction is the distance measured perpendicular to the line of position between the point of impact falling at the greatest distance to the right, and that falling at the greatest distance to the left, excluding wild shots.

Penetration of armor.—The passage of any part of the projectile through all or any part of armor plate. When the projectile passes completely through the armor, complete penetration, or perforation, is said to have occurred.

Perforation of armor.—Complete penetration of armor. *See* Penetration of armor.

Pintle center.—The vertical axis about which a gun and its carriage are traversed.

Plane of departure.—The vertical plane containing the line of departure.

Plane of fire.—The vertical plane containing the axis of the bore when the piece is laid.

Plane of position.—The vertical plane containing a line of position. It is designated in a manner similar to that followed for lines of position.

Plane of site.—A plane containing the line of site and a horizontal line perpendicular to it.

Plotted point (SCA).—A point on the plotted course of the target located by plotting the position of the target at a particular instant.

Point of fall.—*See* Level point.

Point of impact.—The point where the projectile first strikes the ground or other material object.

Pointing.—The operation of giving the piece a designated elevation and direction. There are four cases of pointing:

Case I.—In which the direction and quadrant elevation are both given by means of the sight.

Case I½.—In which the direction is given by the sight and the quadrant elevation is given by a combination of the sight and an elevation scale or graduated drum.

Case II.—In which the direction is given by the sight and the quadrant elevation is given by means of an elevation scale or graduated drum.

Case III.—In which the direction is given by means of an azimuth scale and the quadrant elevation is given by means of an elevation scale or graduated drum.

Position finding.—The process of determining the position of a target with relation to the battery and the determination of a future position upon which to direct the fire.

Position of the target.—Three different positions of the target are considered:

Position of target as predicted—future position of target.—The predicted position of the target at the end of the predicted time of flight.

Position of target at instant of firing—present position of target.—The position of the target at the instant the gun is fired.

Position of target at instant of observation.—The observed position of the target.

Predicted point (SCA).—A point at which it is expected the target will arrive at the end of the dead time.

Predicting.—The process of determining the expected position of the target at some future time.

Predicting interval.—The interval between successive predictions of future positions of the target.

Preparatory fire.—Fire that is conducted for the purpose of determining or verifying corrections to firing data.

Present angular height (azimuth, and so forth) *(AA).*—A term denoting the element of data pertaining to the *present* position of the target; that is, the position at the instant the gun is fired.

Principal lateral deflection angle (AA).—*See* Lateral deflection angle.

Principal vertical deflection angle (AA).—*See* Vertical deflection angle.

Probability factor.—A factor used as an argument in entering the probability tables. It is equal to the error not to be exceeded divided by the probable error.

Probable error.—The error which is as likely as not to be exceeded. A value which in the long run will be exceeded half the time and not exceeded half the time.

Quadrant angle of departure.—The angle between the line of departure and the horizontal.

Quadrant angle of fall.—The angle between the line of fall and the horizontal plane at the level point.

Quadrant angle of site.—The angle between the line of site and the horizontal plane at the origin.

Quadrant elevation.—The vertical angle between the horizontal and the axis of the bore when the gun is ready to fire.

Radian.—The angle at the center of a circle subtended by an arc equal in length to the radius. A convenient angular unit of measurement equal to 1,018.5 mils.

Range (SCA).—The horizontal distance from the gun, observation station, or directing point of a battery to the target, splash, datum point, or other specified point.

Range deviation.—*See* Deviation.

Range difference.—The difference, due to displacement, between the ranges from any two points to a third point.

Range table.—*See* Firing table.

Ranging shots (SCA).—Trial shots fired at a moving target for the purpose of obtaining an adjustment correction.

Rear area.—An area the location of which is such as to render improbable an attack by forces, other than mechanized and motorized, operating on the ground.

Reference numbers.—Arbitrary numbers used in place of actual values in the graduation of certain scales. Their purpose is to avoid the use of positive and negative values.

Regulating point.—A regulating point is an easily recognizable terrain feature, such as a road junction, located at or near the place where the motor column is broken up and the various groups sent to separate areas, or to detrucking or entrucking points.

Relocation (AA).—The process of determining the azimuth and angular height from one station to a point (or target) when the position of the point (or target) with reference to some other station or stations is known.

Relocation (SCA).—The process of determining the range and azimuth from one station to a point (or target) when the range and azimuth from another station to this point are known.

Remaining velocity.—The remaining velocity at any point in the trajectory is the actual velocity in foot-seconds at that point.

Retardation.—The negative acceleration of the projectile.

Richochet.—A glancing rebound of a projectile on impact.

Round.—All of the component parts of ammunition necessary in the firing of one shot.

Salvo.—One round per gun, fired simultaneously or fired in a certain order with a specified time interval between rounds.

Salvo point (SCA).—A point of known range and azimuth at which fire from one or more batteries may be directed.

Self-contained base system (SCA).—A system of position finding in which the target is located in direction and distance from a single station using a self-contained range finder.

Self-contained range finder.—An instrument used to obtain ranges by either the stereoscopic or the coincidence principle.

Sense (AA).—The direction of a point of burst or center of burst of a salvo, with respect to the target, as over or short, right or left, above or below.

Sense (SCA).—The direction of a point of impact or center of impact of a salvo with respect to the target, as over or short, right or left.

Set-forward point (SCA).—A point on the expected course of the target at which it is predicted the target will arrive at the end of the time of flight.

Sight.—A device by which the gun pointer gives the gun the proper direction for firing. It is sometimes called a *telescope.*

Site.—*See* Angle of site.

Slant range (AA).—The hypothenuse of the vertical right triangle in space, the vertical side of which is altitude and the base of which is horizontal range.

Slope of fall.—The degree of inclination of the line of fall to the horizontal. It is usually expressed as a gradient—for instance, 1 on 5, meaning that the projectile drops vertically 1 yard while it is moving horizontally through 5 yards.

Smoke defilade.—*See* Defilade.

Sound lag (AA).—The angular difference between the actual (present) position of the target and the apparent position as indicated by sound.

Sound locator (AA).—An instrument for locating the direction of an aerial target by the sound it emits.

Sound ranging.—The process of locating a target by means of the sounds emitted.

Special protection (AA).—The antiaircraft artillery protection specifically provided a definite element or establishment.

Spot.—An adjustment correction based upon observation of fire; that is, spotting. The measured deviation of an impact or center of impact.

Spotting.—The process of determining the position of a point of impact or burst with respect to the adjusting point.

Straddle.—A salvo which has impacts of opposite sense. Also called a *mixed salvo.*

Striking velocity.—The remaining velocity at the point of impact.

Stripped deviation.—The deviation that would have resulted had there been no personnel errors and no adjustment correction applied.

Subareas (SCA).—Subdivisions of the water area in the field of fire used to assist in the indication and identification of targets.

Summit of trajectory.—The point on the trajectory of maximum altitude.

Superelevation (AA).—That part of the quadrant elevation which allows for the curvature of the trajectory under the conditions actually existing. It is equal to the superelevation under firing table conditions plus (algebraically) the vertical pointing correction.

Synchronization.—A process in which the values indicated by all receiver pointers of an electrical data-transmission system are made to agree exactly with the values set on the corresponding transmitters.

Systematic errors.—Errors of a constant or progressively changing nature that cause the center of impact or burst initially to deviate from the target.

Target angle.—The angle at the target subtended by the observing base line.

Target designating system.—A system for designating to one instrument a target which has already been located by a second instrument. It employs electrical data transmitters and receivers which indicate on one instrument the pointing of another.

Terminal velocity.—The remaining velocity at the point of fall.

Theater of operations.—That part of land and sea in which operations are conducted. It is divided into a combat zone and a communications zone.

Time interval (SCA).—The interval of time between two successive observations made on a moving target during tracking.

Time of flight.—The elapsed time from the instant of departure of the projectile to the instant of impact or to the instant of burst.

Tracking (AA).—The process of following a moving target, by means of sight or sound, for the purpose of following its course.

Tracking (SCA).—The process of making successive observations on a moving target for the purpose of plotting its course.

Trajectory.—The curve described by the center of gravity of the projectile in flight.

Trajectory chart.—A graphical representation of the elements of the trajectory in the vertical plane.

Trial fire.—Preparatory fire having for its purpose the determination of corrections for the battery as a whole to compensate for deviations not corrected for in the normal operations of data computation.

Trial shot corrections.—Corrections made as a result of trial fire which seek to move the center of impact or burst to the trial shot point.

Trial shot point.—A point at which trial fire is conducted.

Trial shots.—Shots fired at a fixed point or target during trial fire.

Twenty-five percent rectangle.—That portion of the dispersion diagram, the dimensions of which are two probable errors in range by two probable errors in deflection, and the center of which is on the center of impact.

Unilateral method (AA).—A method of observing antiaircraft artillery gunfire requiring only one station, which is usually at the battery position.

Unilateral observation (SCA).—Lateral observation of fire from one station only, when the target angle is greater than 100 mils and less than 1,300 mils.

Verification fire.—Preparatory fire having for its purpose the test of the mechanical adjustment of all guns and fire-control equipment of the battery and of the accuracy of the corrections determined as a result of calibration and trial fire.

Vertical base system (SCA).—A system of position finding for moving targets which uses only one observing station equipped with a depression position finder.

Vertical deflection angle (AA).—The vertical angle equal to the algebraic sum of the principal vertical deflection, and the vertical pointing correction.

Approximate vertical deflection angle.—An approximation of the principal vertical deflection angle obtained by multiplying an instantaneous vertical angular velocity by a time of flight.

Principal vertical deflection.—That part of the vertical deflection angle due to the change in the angular height of the target during the time of flight.

Vertical pointing correction.—That part of the vertical deflection angle due to causes other than the travel of the target, such as the corrections due to wind, to muzzle velocity, to atmospheric density, and to vertical adjustment corrections.

Vertical deflection setting (AA).—The setting on the vertical deflection scale of the sighting mechanism of the gun, corresponding to the vertical deflection angle.

Vertical deviation.—*See* Deviation.

Vertical jump.—*See* Jump.

Vertical lead.—The vertical angle by which the gun must be moved from the line of position in order for the trajectory to pass through the target. It is the algebraic sum of the principal vertical deflection, the vertical pointing correction, and the superelevation.

Vertical pointing correction.—*See* Vertical deflection angle.

Volley fire.—Fire in which each piece included in the command fires a specified number of rounds without regard to the other pieces and as rapidly as is consistent with accuracy.

Wild shot.—A shot the armament error of which is greater than four developed probable armament errors and also is greater than six firing-table probable errors, either in range or direction.

Wind.—*See* Ballistic wind.

Wind velocity.—The velocity of the ballistic wind.

Wind-fire angle.—The horizontal angle measured clockwise from the plane of fire to the direction from which the ballistic wind is blowing. It is obtained by subtracting the azimuth of the plane of fire from the wind azimuth.

Yaw.—The angle between the longitudinal axis of the projectile and the tangent to the trajectory at the center of gravity of the projectile.

Zero reader (AA).—A device for indicating when the searchlight and sound locator are pointed at the same azimuth or elevation.

Zone (SCA).—When used with reference to mortar fire or to fire from guns or howitzers using more than one size of powder charge, it refers to the area in which projectiles will fall when one particular size of powder charge is used and the elevation is varied from the minimum to the maximum.

Zone of dispersion.—The zone which would include all impacts of an infinite number of shots fired from a gun using the same firing data for each shot. Practically, the zone is considered to extend four probable errors on each side of the center of impact, and such a zone will include over 99 percent of all shots fired with the same data. The zone of dispersion is also called the *hundred percent zone.*

CHAPTER 6

MOVEMENT TABLES AND CHARTS

TABLE F.—*Movement data, coast artillery mobile weapons*

Class	Caliber and type	Weight of piece and carriage (tons)	Width of tracks	Time to emplace [a]	Rate of march (average) (M. P. H.)	Day's march (average) (miles)
Railway	14-inch gun	365	*Ft. In.* 4 8½	8 hours [b] 10 days [c]	15–20	200
	12-inch gun	166	4 8½	4 hours [b] 10 days [c]	15–20	200
	12-inch mortar.	88	4 8½	3 hours	20	200
	8-inch gun	113	4 8½	3 hours	20	200
155-mm	155-mm gun	12	7 6	1–6 hours	3½	30
Antiaircraft.	90-mm gun	8½	7 4½	20 minutes	25 10 (no lights)	175
	3-inch gun	8	5 6	20 minutes	25 10 (no lights)	175
	37-mm gun	2½	4 10	5 minutes	25 10 (no lights)	175
	Caliber .50 machine gun.	485 lb.	--------	5 minutes [d]	25 10 (no lights)	175

[a] Time to change from firing position to traveling position is approximately the same as that required to emplace in firing position.

[b] Mounted on field platform.

[c] Includes construction of concrete emplacement for all around fire.

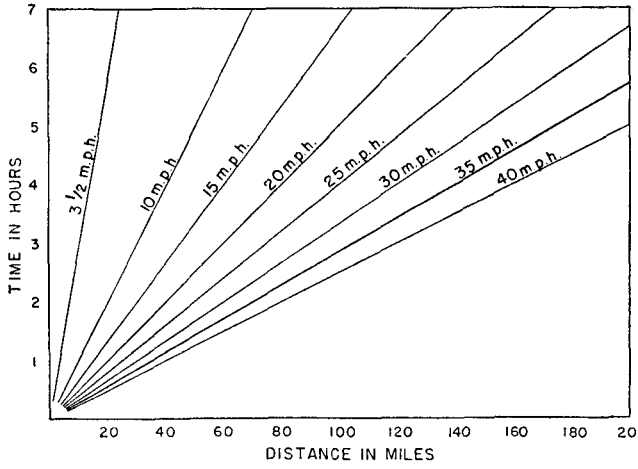
[d] Time to emplace a platoon from trucks. Can be fired effectively from its truck mount.

TABLE G.—*Road spaces for antiaircraft and 155-mm gun artillery**

Units	Road space (closed up)					
	War strength					
	Tractor elements		Truck elements		Total	
	Yards	Miles	Yards	Miles	Yards	Miles
Antiaircraft artillery brigade (3 regiments and attached elements)	-------	-------	12,830	7.3	12,830	7.3
Headquarters and headquarters battery	-------	-------	110	.1	110	.1
Regiment (mobile)	-------	-------	4,060	2.3	4,060	2.3
Headquarters and headquarters battery	-------	-------	360	.3	360	.3
1st battalion (gun)	-------	-------	2,080	1.2	2,080	1.2
Headquarters, headquarters battery, and ammunition train	-------	-------	210	.2	210	.2
Gun battery (3 in battalion)	-------	-------	360	.3	360	.3
Searchlight battery	-------	-------	590	.4	590	.4
2d battalion (automatic weapons)	-------	-------	1,530	.9	1,530	.9
Headquarters, headquarters battery, and ammunition train	-------	-------	160	.1	160	.1
Machine-gun battery (1 in battalion)	-------	-------	320	.2	320	.2
37-mm gun battery (3 in battalion)	-------	-------	280	.2	280	.2
Coast artillery brigade, 155-mm guns (3 regiments and attached elements)	1,620	1.0	10,390	6.0	12,010	6.9
Headquarters and headquarters battery	-------	-------	100	.1	100	.1
Regiment	540	.3	3,400	2.0	3,940	2.3
Headquarters and headquarters battery	-------	-------	360	.4	360	.4
Battalion (3 in regiment)	180	.2	950	.6	1,130	.7
Headquarters, headquarters battery, and ammunition train	-------	-------	370	.3	370	.3
Gun battery	90	.1	240	.2	330	.2

*For road spaces at various speeds, see table I. For time length of column, see table J.

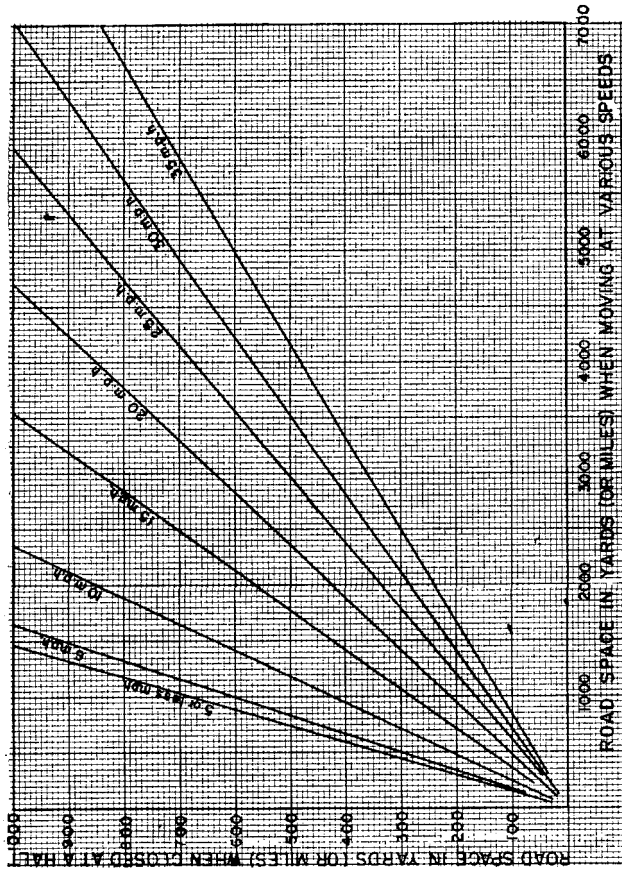
TABLE H.—*Time-distance chart, motor vehicles*



Operation of chart

Known	Required	Operation
Distance and average speed.	Time necessary to complete movement.	From intersection of vertical line through distance scale and the proper speed line, read horizontally the time on the time scale.
Distance and time available.	Average speed necessary.	From intersection of vertical line through distance scale and horizontal line through time scale, read speed in miles per hour on speed line, interpolating if necessary.
Time available and average speed.	Distance covered....	From intersection of horizontal line through time scale and the proper speed line, read along vertical line the distance covered in the distance scale.

TABLE I.—*Road space of motor columns at various speeds*

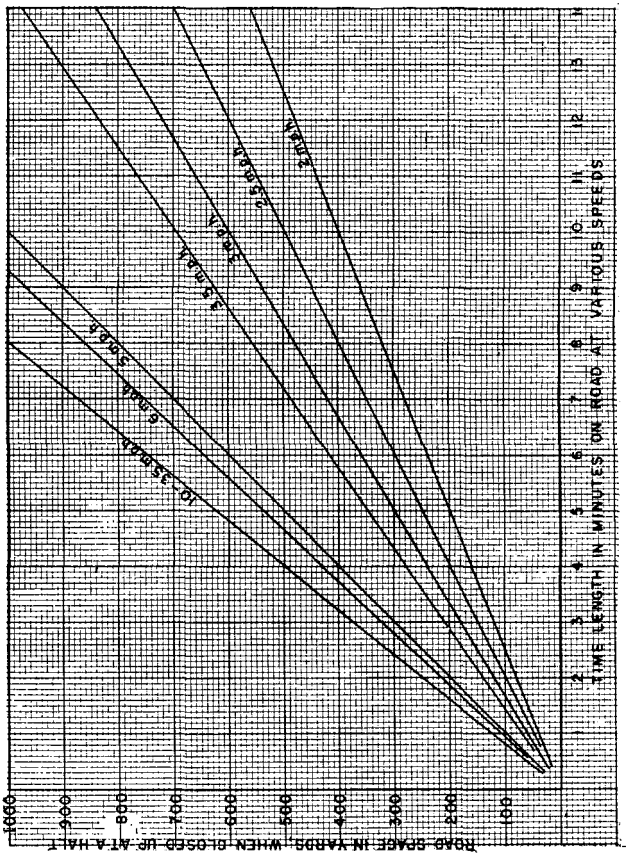


Operation of table I

Enter the vertical scale with the length of the column closed at a halt (see table G). From the intersection of the horizontal line through this point and the proper speed line, read vertically the road space when moving at the selected speed. The road space given is *average* road space

with vehicles closed up to safe driving distance. *Actual* road space may vary 25 percent either way, depending on conditions.

TABLE J.—*Time lengths of motor columns at various speeds*



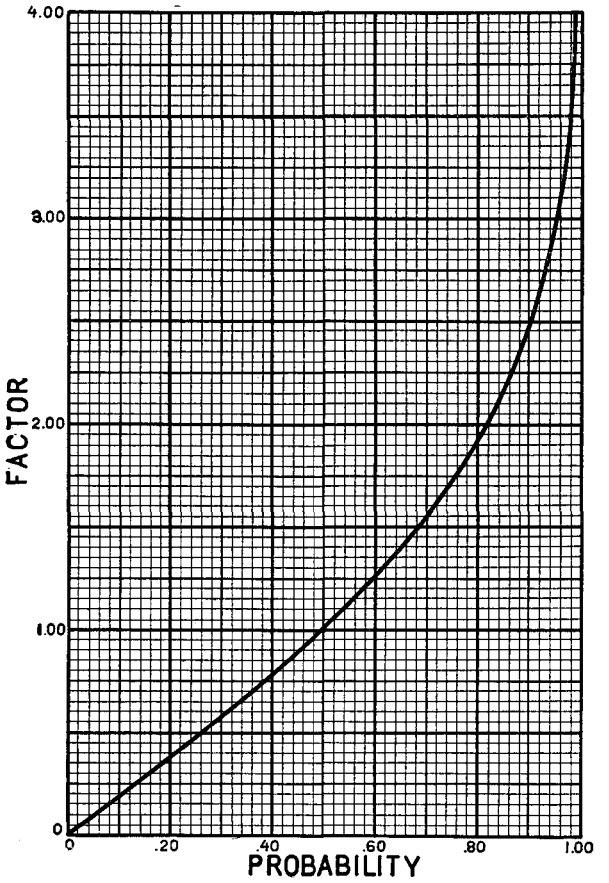
Operation of table J

Enter the vertical scale with the length of the column closed at a halt (see table G). From the intersection of the horizontal line through this point and the proper speed line, read vertically the time length of the column in minutes when moving at that speed. The time length given is the *average* time length with vehicles closed up to safe driving distance. *Actual* time length may vary 25 percent either way, depending on conditions.

CHAPTER 7

PROBABILITY FACTORS

TABLE K.—*Curve of probability factors*



NOTE.—Factor $= \frac{\text{Error}}{\text{Probable error}}$ when the center of impact is on the center of the target and the error is the distance from the center of impact to the outer limits of the target.

TABLE L.—*Table of probability factors*

Part 1.—Factor—probability.

Factor	Probability	Factor	Probability	Factor	Probability	Factor	Probability
0.00	0.000	1.00	0.500	2.00	0.823	3.00	0.957
.05	0.027	1.05	.521	2.05	.833	3.05	.960
.10	.054	1.10	.542	2.10	.843	3.10	.963
.15	.081	1.15	.562	2.15	.853	3.15	.966
.20	.107	1.20	.582	2.20	.862	3.20	.969
.25	.134	1.25	.601	2.25	.871	3.25	.972
.30	.160	1.30	.620	2.30	.879	3.30	.974
.35	.187	1.35	.638	2.35	.887	3.35	.976
.40	.213	1.40	.655	2.40	.895	3.40	.978
.45	.239	1.45	.672	2.45	.902	3.50	.982
.50	.264	1.50	.688	2.50	.908	3.60	.985
.55	.289	1.55	.704	2.55	.914	3.70	.987
.60	.314	1.60	.719	2.60	.920	3.80	.990
.65	.339	1.65	.734	2.65	.926	3.90	.992
.70	.363	1.70	.749	2.70	.931	4.00	.993
.75	.387	1.75	.762	2.75	.936	4.20	.995
.80	.411	1.80	.775	2.80	.941	4.40	.997
.85	.434	1.85	.788	2.85	.945	4.60	.998
.90	.456	1.90	.800	2.90	.949	4.80	.999
.95	.478	1.95	.812	2.95	.953	5.00	.999

TABLE L.—*Table of probability factors*—Continued

Part 2.—Probability—factor.

Probability	Factor	Probability	Factor	Probability	Factor	Probability	Factor
0.01	0.019	0.26	0.492	0.51	1.024	0.76	1.742
.02	.037	.27	.512	.52	1.047	.77	1.780
.03	.056	.28	.532	.53	1.071	.78	1.819
.04	.074	.29	.551	.54	1.096	.79	1.858
.05	.093	.30	.571	.55	1.121	.80	1.900
.06	.112	.31	.592	.56	1.146	.81	1.943
.07	.130	.32	.612	.57	1.172	.82	1.988
.08	.148	.33	.632	.58	1.197	.83	2.035
.09	.167	.34	.652	.59	1.222	.84	2.084
.10	.186	.35	.673	.60	1.248	.85	2.134
.11	.205	.36	.693	.61	1.275	.86	2.185
.12	.224	.37	.714	.62	1.302	.87	2.239
.13	.243	.38	.735	.63	1.329	.88	2.301
.14	.262	.39	.757	.64	1.357	.89	2.365
.15	.281	.40	.778	.65	1.386	.90	2.439
.16	.299	.41	.800	.66	1.415	.91	2.514
.17	.318	.42	.822	.67	1.444	.92	2.596
.18	.337	.43	.843	.68	1.473	.93	2.687
.19	.357	.44	.864	.69	1.505	.94	2.788
.20	.376	.45	.886	.70	1.537	.95	2.906
.21	.395	.46	.909	.71	1.569	.96	3.044
.22	.415	.47	.931	.72	1.602	.97	3.218
.23	.434	.48	.954	.73	1.636	.98	3.451
.24	.453	.49	.977	.74	1.671	.99	3.815
.25	.473	.50	1.000	.75	1.706	1.00	

CHAPTER 8

FORMULAS AND TABLES USED IN THE SOLUTION OF TRIANGLES

(Additional tables, including logarithmic tables, will be found in TM 5–236)

TABLE M.—*Trigonometrical functions*

a. The *six most usual trigonometrical functions* are the ratios defined for a right-angled triangle, as follows:

$$\text{sine} = \frac{\text{opposite side}}{\text{hypothenuse}} \qquad \text{cotangent} = \frac{\text{adjacent side}}{\text{opposite side}}$$

$$\text{cosine} = \frac{\text{adjacent side}}{\text{hypothenuse}} \qquad \text{secant} = \frac{\text{hypothenuse}}{\text{adjacent side}}$$

$$\text{tangent} = \frac{\text{opposite side}}{\text{adjacent side}} \qquad \text{cosecant} = \frac{\text{hypothenuse}}{\text{opposite side}}$$

b. Functions of angles greater than 90°.

Angle	Sine	Cosine	Tangent	Cotangent
x	$+\sin x$	$+\cos x$	$+\tan x$	$+\cot x$
$90° + x$	$+\cos x$	$-\sin x$	$-\cot x$	$-\tan x$
$180° + x$	$-\sin x$	$-\cos x$	$+\tan x$	$+\cot x$
$270° + x$	$-\cos x$	$+\sin x$	$-\cot x$	$-\tan x$

NOTE.—x represents an angle in the first quadrant.

c. General trigonometrical formulas.

Fundamental relations

$$\sin A = \frac{1}{\csc A};\ \cos A = \frac{1}{\sec A};\ \tan A = \frac{1}{\cot A} = \frac{\sin A}{\cos A}$$

$$\csc A = \frac{1}{\sin A};\ \sec A = \frac{1}{\cos A};\ \cot A = \frac{1}{\tan A} = \frac{\cos A}{\sin A}$$

$$\sin^2 A + \cos^2 A = 1;\ \sec^2 A - \tan^2 A = 1;\ \csc^2 A - \cot^2 A = 1$$

Functions of multiple angles

$$\sin 2A = 2 \sin A \cos A$$

$$\cos 2A = 2\cos^2 A - 1 = 1 - 2\sin^2 A = \cos^2 A - \sin^2 A$$

$$\sin 3A = 3 \sin A - 4 \sin^3 A;\ \cos 3A = 4\cos^3 A - 3 \cos A$$

c. *General trigonometrical formulas*—Continued.

Functions of half angles

$$\sin\frac{A}{2}=\pm\sqrt{\frac{1-\cos A}{2}};\ \cos\frac{A}{2}=\pm\sqrt{\frac{1+\cos A}{2}}$$

$$\tan\frac{A}{2}=\frac{1-\cos A}{\sin A}=\frac{\sin A}{1+\cos A}=\pm\sqrt{\frac{1-\cos A}{1+\cos A}}$$

Powers of functions

$\sin^2 A=\frac{1}{2}(1-\cos 2A)$; $\cos^2 A=\frac{1}{2}(1+\cos 2A)$

$\sin^3 A=\frac{1}{4}(3\sin A-\sin 3A)$; $\cos^3 A=\frac{1}{4}(\cos 3A+3\cos A)$

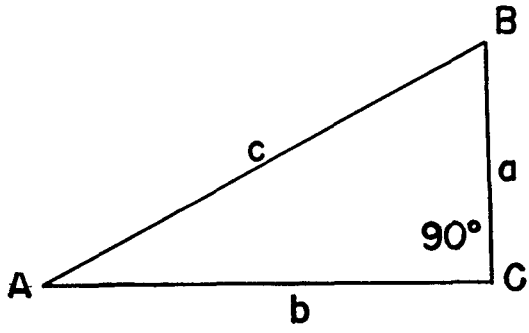
Sum and difference of angles

$$\sin(A\pm B)=\sin A\cos B\pm\cos A\sin B$$
$$\cos(A\pm B)=\cos A\cos B\mp\sin A\sin B$$
$$\tan(A\pm B)=\frac{\tan A\pm\tan B}{1\mp\tan A\tan B}$$

Sums, differences, and products of functions

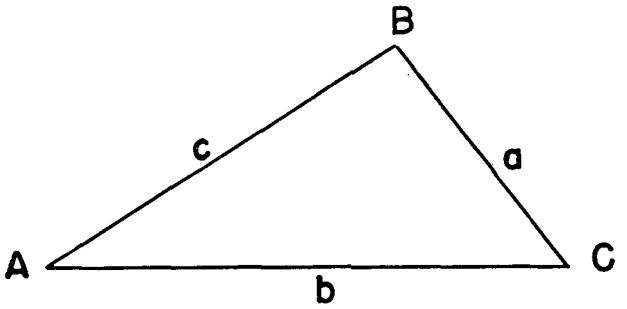
$$\sin A\pm\sin B=2\sin\tfrac{1}{2}(A\pm B)\cos\tfrac{1}{2}(A\mp B)$$
$$\cos A+\cos B=2\cos\tfrac{1}{2}(A+B)\cos\tfrac{1}{2}(A-B)$$
$$\cos A-\cos B=-2\sin\tfrac{1}{2}(A+B)\sin\tfrac{1}{2}(A-B)$$
$$\tan A\pm\tan B=\frac{\sin(A\pm B)}{\cos A\cos B}$$
$$\sin^2 A-\sin^2 B=\sin(A+B)\sin(A-B)$$
$$\cos^2 A-\cos^2 B=-\sin(A+B)\sin(A-B)$$
$$\cos^2 A-\sin^2 B=\cos(A+B)\cos(A-B)$$
$$\sin A\sin B=\tfrac{1}{2}\cos(A-B)-\tfrac{1}{2}\cos(A+B)$$
$$\cos A\cos B=\tfrac{1}{2}\cos(A-B)+\tfrac{1}{2}\cos(A+B)$$
$$\sin A\cos B=\tfrac{1}{2}\sin(A+B)+\tfrac{1}{2}\sin(A-B)$$

TABLE N.—*Solution of right triangles*



Known	Formulas
a, c	$\sin A = \frac{a}{c}$ $\cos B = \frac{a}{c}$ $b = c \cos A = \sqrt{c^2 - a^2}$
a, b	$\tan A = \frac{a}{b}$ $\tan B = \frac{b}{a}$ $c = \frac{a}{\cos B} = \sqrt{a^2 + b^2}$
A, a	$B = 90° - A$ $b = a \cot A$ $c = \frac{a}{\sin A}$
A, b	$B = 90° - A$ $a = b \tan A$ $c = \frac{b}{\cos A}$
A, c	$B = 90° - A$ $a = c \sin A$ $b = c \cos A$

TABLE O.—*Solution of oblique triangles*



Known	Formulas
A, *B*, *a*	$C=180°-(A+B)$ $b=\frac{a \sin B}{\sin A}$ $c=\frac{a \sin (A+B)}{\sin A}$
A, *a*, *b*	$\sin B=\frac{b \sin A}{a}$ $C=180°-(A+B)$ $c=\frac{a \sin C}{\sin A}=\frac{b \sin C}{\sin B}=\sqrt{a^2+b^2-2ab \cos C}$
C, *a*, *b*	$\frac{1}{2}(A+B)=90°-\frac{1}{2}C$ $\tan \frac{1}{2}(A-B)=(a-b) \frac{\tan \frac{1}{2}(A+B)}{(a+b)}$ $A=\frac{1}{2}(A+B)+\frac{1}{2}(A-B)$ $B=\frac{1}{2}(A+B)-\frac{1}{2}(A-B)$ $c=\frac{a \sin C}{\sin A}=\sqrt{a^2+b^2-2ab \cos C}$
a, *b*, *c*	Let $s=\frac{1}{2}(a+b+c)$ $\cos \frac{1}{2}A=\sqrt{\frac{s(s-a)}{bc}}$ $\cos \frac{1}{2}B=\sqrt{\frac{s(s-b)}{ac}}$ $\cos \frac{1}{2}C=\sqrt{\frac{s(s-c)}{ab}}$

TABLE P.—*Natural functions of angles in degrees and tenths*

Degrees	Sin	Cos	Tan	Cot	
0.0	0.0000	1.0000	0.0000	Infinity	90.0
0.2	035	1.0000	035	286.5	89.8
0.4	070	1.0000	070	143.2	89.6
0.6	105	0.9999	105	95.49	89.4
0.8	140	0.9999	140	71.62	89.2
1.0	0.0175	0.9998	0.0175	57.29	89.0
1.2	209	0.9998	209	47.74	88.8
1.4	244	0.9997	244	40.92	88.6
1.6	279	0.9996	279	35.80	88.4
1.8	314	0.9995	314	31.82	88.2
2.0	0.0349	0.9994	0.0349	28.64	88.0
2.2	384	0.9993	384	26.03	87.8
2.4	419	0.9991	419	23.86	87.6
2.6	454	0.9990	454	22.02	87.4
2.8	488	0.9988	489	20.45	87.2
3.0	0.0523	0.9986	0.0524	19.08	87.0
3.2	558	0.9984	559	17.87	86.8
3.4	593	0.9982	594	16.83	86.6
3.6	628	980	629	15.90	86.4
3.8	663	978	664	15.06	86.2
4.0	0.0698	0.9976	0.0699	14.30	86.0
4.2	732	973	734	13.62	85.8
4.4	767	971	769	13.00	85.6
4.6	802	968	805	12.43	85.4
4.8	837	965	840	11.91	85.2
5.0	0.0872	0.9962	0.0875	11.43	85.0
5.2	906	959	910	10.99	84.8
5.4	941	956	945	10.58	84.6
5.6	976	952	981	10.20	84.4
5.8	1011	949	1016	9.85	84.2
6.0	0.1045	0.9945	0.1051	9.5144	84.0
6.2	080	942	086	2052	83.8
6.4	115	938	122	8.9152	83.6
6.6	149	934	157	6427	83.4
6.8	184	930	192	3863	83.2
	Cos	Sin	Cot	Tan	Degrees

TABLE P.—*Natural functions of angles in degrees and tenths*—Continued

Degrees	Sin	Cos	Tan	Cot	
7.0	0.1219	0.9925	0.1228	8.1443	83.0
7.2	253	921	263	7.9158	82.8
7.4	288	917	299	.6996	82.6
7.6	323	912	334	.4947	82.4
7.8	357	907	370	.3002	82.2
8.0	0.1392	0.9903	0.1405	7.1154	82.0
8.2	426	898	441	6.9395	81.8
8.4	461	893	477	7720	81.6
8.6	495	888	512	6122	81.4
8.8	530	882	548	4596	81.2
9.0	0.1564	0.9877	0.1584	6.3138	81.0
9.2	599	871	620	1742	80.8
9.4	633	866	655	0405	80.6
9.6	668	860	691	5.9124	80.4
9.8	702	854	727	7894	80.2
10.0	0.1736	0.9848	0.1763	5.6713	80.0
10.2	771	842	799	5578	79.8
10.4	805	836	835	4486	79.6
10.6	840	829	871	3435	79.4
10.8	874	823	908	2422	79.2
11.0	0.1908	0.9816	0.1944	5.1446	79.0
11.2	942	810	980	0504	78.8
11.4	977	803	0.2016	4.9594	78.6
11.6	0.2011	796	053	8716	78.4
11.8	045	789	089	7867	78.2
12.0	0.2079	0.9781	0.2126	4.7046	78.0
12.2	113	774	162	6252	77.8
12.4	147	767	199	5483	77.6
12.6	181	759	235	4737	77.4
12.8	215	751	272	4015	77.2
13.0	0.2250	0.9744	0.2309	4.3315	77.0
13.2	284	736	345	2635	76.8
13.4	317	728	382	1976	76.6
13.6	351	720	419	1335	76.4
13.8	385	711	456	0713	76.2
	Cos	Sin	Cot	Tan	Degrees

TABLE P.—*Natural functions of angles in degrees and tenths*—Continued

Degrees	Sin	Cos	Tan	Cot	
14.0	0.2419	0.9703	0.2493	4.0108	76.0
14.2	453	694	530	3.9520	75.8
14.4	487	686	568	8947	75.6
14.6	521	677	605	8391	75.4
14.8	554	668	642	7848	75.2
15.0	0.2588	0.9659	0.2679	3.7321	75.0
15.2	622	650	717	6806	74.8
15.4	656	641	754	6305	74.6
15.6	689	632	792	5816	74.4
15.8	723	622	830	5339	74.2
16.0	0.2756	0.9613	0.2867	3.4874	74.0
16.2	790	603	905	4420	73.8
16.4	823	593	943	3977	73.6
16.6	857	5 3	981	3544	73.4
16.8	890	573	0.3019	3122	73.2
17.0	0.2924	0.9563	0.3057	3.2709	73.0
17.2	957	553	096	2305	72.8
17.4	990	542	134	1910	72.6
17.6	0.3024	532	172	1524	72.4
17.8	057	521	211	1146	72.2
18.0	0.3090	0.9511	0.3249	3.0777	72.0
18.2	123	500	288	0415	71.8
18.4	156	489	327	0061	71.6
18.6	190	478	365	2.9714	71.4
18.8	223	466	404	9375	71.2
19.0	0.3256	0.9455	0.3443	2.9042	71.0
19.2	289	444	482	8716	70.8
19.4	322	432	522	8397	70.6
19.6	355	421	561	8083	70.4
19.8	387	409	600	7776	70.2
20.0	0.3420	0.9397	0.3640	2.7475	70.0
20.2	453	385	679	7179	69.8
20.4	486	373	719	6889	69.6
20.6	518	361	759	6605	69.4
20.8	551	348	799	6325	69.2
	Cos	Sin	Cot	Tan	Degrees

TABLE P.—*Natural functions of angles in degrees and tenths*—Continued

Degrees	Sin	Cos	Tan	Cot	
21.0	0.3584	0.9336	0.3839	2.6051	69.0
21.2	616	323	879	5782	68.8
21.4	649	311	919	5517	68.6
21.6	681	298	959	5257	68.4
21.8	714	285	0.4000	5002	68.2
22.0	0.3746	0.9272	0.4040	2.4751	68.0
22.2	778	259	081	4504	67.8
22.4	811	245	122	4262	67.6
22.6	843	232	163	4023	67.4
22.8	875	219	204	3789	67.2
23.0	0.3907	0.9205	0.4245	2.3559	67.0
23.2	939	191	286	3332	66.8
23.4	971	178	327	3109	66.6
23.6	0.4003	164	369	2889	66.4
23.8	035	150	411	2673	66.2
24.0	0.4067	0.9135	0.4452	2.2460	66.0
24.2	099	121	494	2251	65.8
24.4	131	107	536	2045	65.6
24.6	163	092	578	1842	65.4
24.8	195	078	621	1642	65.2
25.0	0.4226	0.9063	0.4663	2.1445	65.0
25.2	258	048	706	1251	64.8
25.4	289	033	748	1060	64.6
25.6	321	018	791	0872	64.4
25.8	352	003	834	0686	64.2
26.0	0.4384	0.8988	0.4877	2.0503	64.0
26.2	415	973	921	0323	63.8
26.4	446	957	964	0145	63.6
26.6	478	942	0.5008	1.9970	63.4
26.8	509	926	051	9797	63.2
27.0	0.4540	0.8910	0.5095	1.9626	63.0
27.2	571	894	139	458	62.8
27.4	602	878	184	292	62.6
27.6	633	862	228	128	62.4
27.8	664	846	272	1.8967	62.2
	Cos	Sin	Cot	Tan	Degrees

TABLE P.—*Natural functions of angles in degrees and tenths*—Continued

Degrees	Sin	Cos	Tan	Cot	
28.0	0.4695	0.8829	0.5317	1.8807	62.0
28.2	726	813	362	650	61.8
28.4	756	796	407	495	61.6
28.6	787	780	452	341	61.4
28.8	818	763	498	190	61.2
29.0	0.4848	0.8746	0.5543	1.8040	61.0
29.2	879	729	589	1.7893	60.8
29.4	909	712	635	747	60.6
29.6	939	695	681	603	60.4
29.8	970	678	727	461	60.2
30.0	0.5000	0.8660	0.5774	1.7321	60.0
30.2	030	643	820	182	59.8
30.4	060	625	867	045	59.6
30.6	090	607	914	1.6909	59.4
30.8	120	590	961	775	59.2
31.0	0.5150	0.8572	0.6009	1.6643	59.0
31.2	180	554	056	512	58.8
31.4	210	536	104	383	58.6
31.6	240	517	152	255	58.4
31.8	270	499	200	128	58.2
32.0	0.5299	0.8480	0.6249	1.6003	58.0
32.2	329	462	297	1.5880	57.8
32.4	358	443	346	757	57.6
32.6	388	425	395	637	57.4
32.8	417	406	445	517	57.2
33.0	0.5446	0.8387	0.6494	1.5399	57.0
33.2	476	368	544	282	56.8
33.4	505	348	594	166	56.6
33.6	534	329	644	051	56.4
33.8	563	310	694	1.4938	56.2
34.0	0.5592	0.8290	0.6745	1.4826	56.0
34.2	621	271	796	715	55.8
34.4	650	251	847	605	55.6
34.6	678	231	899	496	55.4
34.8	707	211	950	388	55.2
'	Cos	Sin	Cot	Tan	Degrees

TABLE P.—*Natural functions of angles in degrees and tenths*—Continued

Degrees	Sin	Cos	Tan	Cot	
35.0	0.5736	0.8192	0.7002	1.4281	55.0
35.2	764	171	054	176	54.8
35.4	793	151	107	071	54.6
35.6	821	131	159	1.3968	54.4
35.8	850	111	212	865	54.2
36.0	0.5878	0.8090	0.7265	1.3764	54.0
36.2	906	070	319	663	53.8
36.4	934	049	373	564	53.6
36.6	962	028	427	465	53.4
36.8	990	007	481	367	53.2
37.0	0.6018	0.7986	0.7536	1.3270	53.0
37.2	046	965	590	175	52.8
37.4	074	944	646	079	52.6
37.6	101	923	701	1.2985	52.4
37.8	129	902	757	892	52.2
38.0	0.6157	0.7880	0.7813	1.2799	52.0
38.2	184	859	869	708	51.8
38.4	211	837	926	617	51.6
38.6	239	815	983	527	51.4
38.8	266	793	0.8040	437	51.2
39.0	0.6293	0.7771	0.8098	1.2349	51.0
39.2	320	749	156	261	50.8
39.4	347	727	214	174	50.6
39.6	374	705	273	088	50.4
39.8	401	683	332	002	50.2
40.0	0.6428	0.7660	0.8391	1.1918	50.0
40.2	455	638	451	833	49.8
40.4	481	615	511	750	49.6
40.6	508	593	571	667	49.4
40.8	534	570	632	585	49.2
41.0	0.6561	0.7547	0.8693	1.1504	49.0
41.2	587	524	754	423	48.8
41.4	613	501	816	343	48.6
41.6	639	478	878	263	48.4
41.8	665	455	941	184	48.2
	Cos	Sin	Cot	Tan	Degrees

TABLE P.—*Natural functions of angles in degrees and tenths*—Continued

Degrees	Sin	Cos	Tan	Cot	
42.0	0.6691	0.7431	0.9004	1.1106	48.0
42.2	717	408	067	028	47.8
42.4	743	385	131	1.0951	47.6
42.6	769	361	195	875	47.4
42.8	794	337	260	799	47.2
43.0	0.6820	0.7314	0.9325	1.0724	47.0
43.2	845	290	391	649	46.8
43.4	871	266	457	575	46.6
43.6	896	242	523	501	46.4
43.8	921	218	590	428	46.2
44.0	0.6947	0.7193	0.9657	1.0355	46.0
44.2	972	169	725	283	45.8
44.4	997	145	793	212	45.6
44.6	0.7022	120	861	141	45.4
44.8	046	096	930	070	45.2
45.0	0.7071	0.7071	1.0000	1.0000	45.0
	Cos	Sin	Cot	Tan	Degrees

TABLE Q.—*Natural functions of angles in mils*

Mils	Sin	Cos	Tan	Cot	
0	0.0000	1.0000	0.0000	Infinity	1600
2	020	000	019	509.3	1598
4	039	0.9999	039	254.6	96
6	059	999	059	169.8	94
8	079	999	079	127.3	1592
10	0.0098	0.9999	0.0098	101.9	90
12	118	999	117	84.88	88
14	137	999	137	72.75	86
16	157	999	157	63.66	84
18	177	998	177	56.59	1582
20	0.0196	0.9998	0.0196	50.92	80
22	216	998	216	46.29	78
24	236	997	236	42.43	76
26	255	997	255	39.17	74
28	275	996	275	36.37	1572
	Cos	Sin	Cot	Tan	Mils

TABLE Q.—*Natural functions of angles in mils*—Continued

Mils	Sin	Cos	Tan	Cot	
30	0. 0295	0. 9996	0. 0295	33. 94	70
32	314	995	314	31. 82	68
34	334	994	334	29. 95	66
36	353	994	354	28. 28	64
38	373	993	373	26. 79	1562
40	0. 0393	0. 9992	0. 0393	25. 45	60
42	412	992	413	24. 24	58
44	432	991	432	23. 14	56
46	452	990	452	22. 13	54
48	471	989	472	21. 20	1552
50	0. 0491	0. 9988	0. 0491	20. 36	50
52	510	987	511	19. 58	48
54	530	986	531	18. 85	46
56	550	985	550	18. 17	44
58	570	984	570	17. 54	1542
60	0. 0589	0. 9983	0. 0590	16. 96	40
62	608	982	609	16. 41	38
64	628	980	629	15. 89	36
66	648	979	649	15. 41	34
68	667	978	669	14. 96	1532
70	0. 0687	0. 9976	0. 0688	14. 53	30
72	706	975	708	14. 12	28
74	726	974	728	13. 74	26
76	745	972	748	13. 38	24
78	765	971	767	13. 03	1522
80	0. 0785	0. 9969	0. 0787	12. 71	20
82	804	968	807	12. 40	18
84	824	966	827	12. 10	16
86	843	964	846	11. 82	14
88	863	963	866	11. 55	1512
90	0. 0882	0. 9961	0. 0886	11. 29	10
92	902	959	906	11. 04	8
94	922	957	926	10. 81	6
96	941	956	945	10. 58	4
98	961	954	965	10. 36	1502
	Cos	Sin	Cot	Tan	Mils

TABLE Q.—*Natural functions of angles in mils*—Continued

Mils	Sin	Cos	Tan	Cot	
100	0.0980	0.9952	0.0985	10.15	1500
2	.1000	950	.1005	9.953	1498
4	019	948	025	760	96
6	038	946	044	575	94
8	058	944	064	396	1492
110	0.1078	0.9942	0.1084	9.224	90
12	097	940	104	058	88
14	117	937	124	8.898	86
16	136	935	144	743	84
18	156	933	164	593	1482
120	0.1175	0.9931	0.1184	8.449	80
22	195	928	204	309	78
24	214	926	223	174	76
26	234	924	243	043	74
28	253	921	263	7.916	1472
130	0.1273	0.9919	0.1283	7.793	70
32	292	916	303	673	66
34	312	914	323	558	66
36	331	911	343	445	64
38	351	908	363	336	1462
140	0.1370	0.9906	0.1383	7.230	60
42	390	903	403	127	58
44	409	900	423	026	56
46	428	898	443	6.929	54
48	448	895	463	834	1452
150	0.1467	0.9892	0.1483	6.741	50
52	487	889	503	651	48
54	506	886	524	564	46
56	526	883	544	478	44
58	545	880	564	395	1442
160	0.1564	0.9877	0.1584	6.314	40
62	584	874	604	234	38
64	603	871	624	157	36
66	623	868	644	082	34
68	642	864	665	008	1432
	Cos	Sin	Cot	Tan	Mils

TABLE Q.—*Natural functions of angles in mils*—Continued

Mils	Sin	Cos	Tan	Cot	
170	0. 1661	0. 9861	0. 1685	5. 936	30
72	681	858	705	866	28
74	700	855	725	797	26
76	719	851	745	730	24
78	739	848	766	664	1422
180	0. 1758	0. 9844	0. 1786	5. 600	20
82	777	841	806	537	18
84	797	837	826	475	16
86	816	834	847	415	14
88	835	830	867	357	1412
190	0. 1855	0. 9827	0. 1887	5. 299	10
92	874	823	908	242	8
94	893	819	928	187	6
96	912	815	948	132	4
98	932	812	969	079	1402
200	0. 1951	0. 9808	0. 1989	5. 0273	1400
02	970	804	0. 2010	4. 9763	1398
04	989	800	030	262	96
06	0. 2009	796	050	4. 8771	94
08	028	792	071	288	1392
210	0. 2047	0. 9788	0. 2091	4. 7815	90
12	066	784	112	350	88
14	086	780	132	4. 6895	86
16	105	776	153	448	84
18	124	772	174	009	1382
220	0. 2143	0. 9768	0. 2194	4. 5578	80
22	162	763	215	154	78
24	181	759	235	4. 4737	76
26	201	755	256	328	74
28	220	751	277	4. 3926	1372
230	0. 2239	0. 9746	0. 2297	4. 3531	70
32	258	742	318	143	68
34	277	737	339	4. 2762	66
36	296	733	359	386	64
83	315	728	380	017	1362
	Cos	Sin	Cot	Tan	Mils

TABLE Q.—*Natural functions of angles in mils*—Continued

Mils	Sin	Cos	Tan	Cot	
240	0.2335	0.9724	0.2401	4.1653	60
42	354	719	422	295	58
44	373	715	442	4.0944	56
46	392	710	463	598	54
48	411	705	484	257	1352
250	0.2430	0.9700	0.2505	3.9923	50
52	449	696	526	593	48
54	468	691	547	268	46
56	487	686	568	3.8947	44
58	506	681	589	632	1342
260	0.2525	0.9676	0.2610	3.8322	40
62	544	671	631	016	38
64	563	666	652	3.7715	36
66	582	661	673	419	34
68	601	656	694	126	1332
270	0.2620	0.9651	0.2715	3.6838	30
72	639	646	736	554	28
74	658	641	757	273	26
76	677	635	778	3.5997	24
78	696	630	799	725	1322
280	0.2714	0.9625	0.2820	3.5457	20
82	733	619	842	193	18
84	752	614	863	3.4932	16
86	771	608	884	675	14
88	790	603	905	420	1312
290	0.2809	0.9597	0.2927	3.4169	10
92	828	592	948	3.3922	8
94	846	586	969	678	6
96	865	581	991	438	4
98	884	575	0.3012	201	1302
300	0.2903	0.9569	0.3034	3.2966	1300
02	922	564	055	734	1298
04	940	558	076	506	96
06	959	552	098	280	94
08	978	546	119	057	1292
	Cos	Sin	Cot	Tan	Mils

TABLE Q.—*Natural functions of angles in mils*—Continued

Mils	Sin	Cos	Tan	Cot	
310	0.2997	0.9540	0.3141	3.1837	90
12	0.3015	535	163	620	88
14	034	529	184	405	86
16	053	523	206	193	84
18	072	517	228	3.0984	1282
320	0.3090	0.9511	0.3249	3.0777	80
22	109	505	271	572	78
24	128	498	293	370	76
26	146	492	314	171	74
28	165	486	336	2.9974	1272
330	0.3183	0.9480	0.3358	2.9779	70
32	202	474	380	587	68
34	221	467	402	396	66
36	239	461	424	208	64
38	258	455	446	022	1262
340	0.3276	0.9448	0.3468	2.8838	60
42	295	442	490	656	58
44	313	435	512	476	56
46	332	428	534	298	54
48	350	422	556	122	1252
350	0.3369	0.9415	0.3578	2.7948	50
52	387	409	600	776	48
54	406	402	622	606	46
56	424	395	645	438	44
58	443	389	667	271	1242
360	0.3461	0.9382	0.3689	2.7106	40
62	480	375	712	2.6943	38
64	498	368	734	781	36
66	516	361	756	622	34
68	535	354	779	464	1232
370	0.3553	0.9348	0.3801	2.6308	30
72	572	341	824	153	28
74	590	334	846	2.6000	26
76	608	326	869	2.5848	24
78	626	319	891	698	1222
	Cos	Sin	Cot	Tan	Mils

TABLE Q.—*Natural functions of angles in mils*—Continued

Mils	Sin	Cos	Tan	Cot	
380	0.3645	0.9312	0.3914	2.5550	20
82	663	305	937	403	18
84	681	298	959	257	16
86	700	291	982	113	14
88	718	283	0.4005	2.4970	1212
390	0.3736	0.9276	0.4028	2.4829	10
92	754	268	050	689	8
94	772	261	073	550	6
96	791	253	096	413	4
98	809	246	119	277	1202
400	0.3827	0.9239	0.4142	2.4142	1200
02	845	231	165	009	1198
04	863	224	188	2.3877	96
06	881	216	211	746	94
08	899	209	235	616	1192
410	0.3917	0.9201	0.4258	2.3487	90
12	935	193	281	360	88
14	954	185	304	234	86
16	972	178	327	109	84
18	990	170	351	2.2985	1182
420	0.4008	0.9162	0.4374	2.2862	80
22	026	154	398	740	78
24	043	146	421	620	76
26	061	138	445	500	74
28	079	130	468	381	1172
430	0.4097	0.9122	0.4492	2.2264	70
32	115	114	515	148	68
34	133	106	539	032	66
36	151	098	563	2.1918	64
38	169	090	586	804	1162
440	0.4187	0.9081	0.4610	2.1692	60
42	204	073	634	580	58
44	222	065	658	470	56
46	240	057	682	360	54
48	258	048	706	251	1152
	Cos	Sin	Cot	Tan	Mils

TABLE Q.—*Natural functions of angles in mils*—Continued

Mils	Sin	Cos	Tan	Cot	
450	0.4276	0.9040	0.4730	2.1143	50
52	293	032	754	036	48
54	311	023	778	2.0930	46
56	329	015	802	825	44
58	346	006	826	721	1142
460	0.4364	0.8998	0.4850	2.0617	40
62	382	989	875	515	38
64	399	980	899	413	36
66	417	972	923	312	34
68	435	963	948	211	1132
470	0.4452	0.8954	0.4972	2.0112	30
72	470	945	997	013	28
74	487	937	0.5021	1.9915	26
76	505	928	046	818	24
78	522	919	071	722	1122
480	0.4540	0.8910	0.5095	1.9626	20
82	557	901	120	531	18
84	575	892	145	437	16
86	592	883	170	343	14
88	610	874	195	251	1112
490	0.4627	0.8865	0.5220	1.9159	10
92	645	856	245	067	8
94	662	847	270	1.8977	6
96	679	838	295	887	4
98	697	829	320	797	1102
500	0.4714	0.8819	0.5345	1.8709	1100
02	731	810	370	621	1098
04	749	801	396	533	96
06	766	791	421	446	94
08	783	782	447	360	1092
510	0.4800	0.8773	0.5472	1.8275	90
12	818	763	498	190	88
14	835	754	523	106	86
16	852	744	549	022	84
18	869	735	575	1.7939	1082
	Cos	Sin	Cot	Tan	Mils

TABLE Q.—*Natural functions of angles in mils*—Continued

Mils	Sin	Cos	Tan	Cot	
520	0.4886	0.8725	0.5600	1.7856	80
22	903	715	626	774	78
24	920	706	652	693	76
26	938	696	678	612	74
28	955	686	704	532	1072
530	0.4972	0.8677	0.5730	1.7452	70
32	989	667	756	373	68
34	0.5006	657	782	294	66
36	023	647	809	216	64
38	040	637	835	139	1062
540	0.5057	0.8627	0.5861	1.7062	60
42	074	617	888	1.6985	58
44	090	607	914	909	56
46	107	597	941	834	54
48	124	587	967	759	1052
550	0.5141	0.8577	0.5994	1.6684	50
52	158	567	0.6021	610	48
54	175	557	047	536	46
56	192	547	074	463	44
58	208	537	101	391	1042
560	0.5225	0.8526	0.6128	1.6319	40
62	242	516	155	247	38
64	258	506	182	176	36
66	275	496	209	105	34
68	292	485	237	035	1032
570	0.5308	0.8475	0.6264	1.5965	30
72	325	464	291	895	28
74	342	454	319	826	26
76	358	443	346	758	24
78	375	433	374	689	1022
580	0.5391	0.8422	0.6401	1.5622	20
82	408	412	429	554	18
84	424	401	457	487	16
86	441	390	485	421	14
88	457	380	513	355	1012
	Cos	Sin	Cot	Tan	Mils

TABLE Q.—*Natural functions of angles in mils*—Continued

Mils	Sin	Cos	Tan	Cot	
590	0.5474	0.8369	0.6541	1.5289	10
92	490	358	569	223	8
94	507	347	597	159	6
96	523	336	625	094	4
98	539	326	653	030	1002
600	0.5556	0.8315	0.6682	1.4966	1000
02	572	304	710	903	998
04	588	293	739	840	96
06	605	282	767	777	94
08	621	271	796	715	992
610	0.5637	0.8260	0.6825	1.4653	90
12	653	249	854	591	88
14	670	238	883	530	86
16	686	226	912	469	84
18	702	215	941	408	982
620	0.5718	0.8204	0.6970	1.4348	80
22	734	193	999	288	78
24	750	182	0.7028	229	76
26	766	170	058	169	74
28	782	159	087	111	972
630	0.5798	0.8148	0.7117	1.4052	70
32	814	136	146	1.3994	68
34	830	125	176	936	66
36	846	113	206	878	64
38	862	102	236	821	962
640	0.5878	0.8090	0.7266	1.3764	60
42	894	079	296	707	58
44	910	067	326	651	56
46	925	055	356	595	54
48	941	044	386	539	952
650	0.5957	0.8032	0.7417	1.3484	50
52	973	020	447	428	48
54	989	009	478	373	46
56	0.6004	0.7997	508	319	44
58	020	985	539	264	942
	Cos	Sin	Cot	Tan	Mils

TABLE Q.—*Natural functions of angles in mils*—Continued

Mils	Sin	Cos	Tan	Cot	
660	0. 6035	0. 7973	0. 7570	1. 3210	40
62	051	961	601	157	38
64	067	949	632	103	36
66	082	938	663	050	34
68	098	926	694	1. 2997	932
670	0. 6114	0. 7914	0. 7725	1. 2944	30
72	129	902	757	892	28
74	145	890	788	840	26
76	160	877	820	788	24
78	176	865	852	736	922
680	0. 6191	0. 7853	0. 7883	1. 2685	20
82	206	841	915	634	18
84	222	829	947	583	16
86	237	817	979	532	14
88	252	804	0. 8012	482	912
690	0. 6268	0. 7792	0. 8044	1. 2432	10
92	283	780	076	382	8
94	298	767	109	332	6
96	314	755	141	283	4
98	329	743	174	234	902
700	0. 6344	0. 7730	0. 8207	1. 2185	900
02	359	718	240	136	898
04	374	705	273	088	96
06	389	693	306	040	94
08	404	680	339	1. 1992	892
710	0. 6420	0. 7667	0. 8372	1. 1944	90
12	435	655	406	896	88
14	450	642	439	849	86
16	465	630	473	802	84
18	480	617	507	755	882
720	0. 6495	0. 7604	0. 8541	1. 1709	80
22	510	591	575	662	78
24	524	579	609	616	76
26	539	566	643	570	74
28	554	553	678	524	872
	Cos	Sin	Cot	Tan	Mils

TABLE Q.—*Natural functions of angles in mils*—Continued

Mils	Sin	Cos	Tan	Cot	
730	0. 6569	0. 7540	0. 8712	1. 1478	70
32	584	527	747	433	68
34	598	514	781	388	66
36	613	501	816	343	64
38	628	488	851	298	862
740	0. 6643	0. 7475	0. 8886	1. 1253	60
42	657	462	921	209	58
44	672	449	957	165	56
46	686	436	992	121	54
48	701	423	0. 9028	077	852
750	0. 6716	0. 7410	0. 9064	1. 1033	50
52	730	396	099	1. 0990	48
54	745	383	135	947	46
56	759	370	171	903	44
58	774	357	208	861	842
760	0. 6788	0. 7343	0. 9244	1. 0818	40
62	802	330	280	775	38
64	817	317	317	733	36
66	831	303	354	691	34
68	846	290	391	649	832
770	0. 6860	0. 7276	0. 9428	1. 0607	30
72	874	263	465	565	28
74	888	249	502	524	26
76	903	236	540	483	24
78	917	222	577	442	822
780	0. 6931	0. 7209	0. 9615	1. 0401	20
82	945	195	653	360	18
84	959	181	691	319	16
86	973	168	729	279	14
88	987	154	767	238	812
790	0. 7001	0. 7140	0. 9806	1. 0198	10
92	015	126	844	158	8
94	029	113	883	119	6
96	043	099	922	079	4
98	057	085	961	040	2
800	0. 7071	0. 7071	1. 0000	1. 0000	800
	Cos	Sin	Cot	Tan	Mils

TABLE R.—*Conversion tables*

Part 1.—Linear.

	Inches	Feet	Yards	Miles	Meters	Nautical miles
Inches	1	0.0833	0.0278	0.000016	0.0254	0.000014
Feet	12	1	.333	.00019	.305	.00016
Yards	36	3	1	.00057	.914	.00049
Miles	63,360	5,280	1,760	1	1,609	.868
Meters	39.4	3.28	1.094	.00062	1	.00054
Nautical miles	72,962	6,080	2,027	1.15	1,853	1

Rod = 5.5 yds.

Part 2.—Angular.

	Circle	Mils	Degrees	Minutes	Seconds	Radians
Circle	1	6,400	360	21,600	1,296,000	2π
Mils	.00016	1	.0563	3.375	202.5	0.00098
Degrees	.00276	17.78	1	60	3,600	.0175
Minutes	.000046	.296	.0167	1	60	.00029
Seconds	.0000008	.00493	.00028	.0167	1	.0000049
Radians	.159	1,018.6	57.29	3,437.7	206,265	1

NOTE.—See tables S and T.

Part 3.—Velocity.

	Miles per hour	Yards per minute	Yards per second	Feet per second	Kilometers per hour	Meters per second	Knots
Miles per hour	1	29.3	0.489	1.47	1.61	0.447	0.868
Yards per minute	.034	1	.167	.05	.0549	.0152	.0296
Yards per second	2.04	60	1	3	3.29	.915	1.78
Feet per second	.682	20	.333	1	1.10	.305	.592
Kilometers per hour	.621	18.2	.304	.911	1	.278	.540
Meters per second	2.238	65.4	1.092	3.282	3.60	1	1.944
Knots	1.15	33.8	.563	1.69	1.85	0.515	1

TABLE S.—*Conversion of mils into degrees and minutes*

(Conversion factor—1 mil equals 0.05625 degrees equals 3.37500 minutes)

Mils	00	10	20	30	40
0	00°00′.00	00°33′.75	1°07′.50	1°41′.25	2°15′.00
100	5 37. 50	6 11. 25	6 45. 00	7 18. 75	7 52. 50
200	11 15. 00	11 48. 75	12 22. 50	12 56. 25	13 30. 00
300	16 52. 50	17 26. 25	18 00. 00	18 33. 75	19 07. 50
400	22 30. 00	23 03. 75	23 37. 50	24 11. 25	24 45. 00
500	28 07. 50	28 41. 25	29 15. 00	29 48. 75	30 22. 50
600	33 45. 00	34 18. 75	34 52. 50	35 26. 25	36 00. 00
700	39 22. 50	39 56. 25	40 30. 00	41 03. 75	41 37. 50
800	45 00. 00	45 33. 75	46 07. 50	46 41. 25	47 15. 00
900	50 37. 50	51 11. 25	51 45. 00	52 18. 75	52 52. 50
1, 000	56 15. 00	56 48. 75	57 22. 50	57 56. 25	58 30. 00
1, 100	61 52. 50	62 26. 25	63 00. 00	63 33. 75	64 07. 50
1, 200	67 30. 00	68 03. 75	68 37. 50	69 11. 25	69 45. 00
1, 300	73 07. 50	73 41. 25	74 15. 00	74 48. 75	75 22. 50
1, 400	78 45. 00	79 18. 75	79 52. 50	80 26. 25	81 00. 00
1, 500	84 22. 50	84 56. 25	85 30. 00	86 03. 75	86 37. 50

Mils	50	60	70	80	90
0	2°48′.75	3°22′.50	3°56′.25	4°30′.00	5°03′.75
100	8 26. 25	9 00. 00	9 33. 75	10 07. 50	10 41. 25
200	14 03. 75	14 37. 50	15 11. 25	15 45. 00	16 18. 75
300	19 41. 25	20 15. 00	20 48. 75	21 22. 50	21 56. 25
400	25 18. 75	25 52. 50	26 26. 25	27 00. 00	27 33. 75
500	30 56. 25	31 30. 00	32 03. 75	32 37. 50	33 11. 25
600	36 33. 75	37 07. 50	37 41. 25	38 15. 00	38 48. 75
700	42 11. 25	42 45. 00	43 18. 75	43 52. 50	44 26. 25
800	47 48. 75	48 22. 50	48 56. 25	49 30. 00	50 03. 75
900	53 26. 25	54 00. 00	54 33. 75	55 07. 50	55 41. 25
1, 000	59 03. 75	59 37. 50	60 11. 25	60 45. 00	61 18. 75
1, 100	64 41. 25	65 15. 00	65 48. 75	66 22. 50	66 56. 25
1, 200	70 18. 75	70 52. 50	71 26. 25	72 00. 00	72 33. 75
1, 300	75 56. 25	76 30. 00	77 03. 75	77 37. 50	78 11. 25
1, 400	81 33. 75	82 07. 50	82 41. 25	83 15. 00	83 48. 75
1, 500	87 11. 25	87 45. 00	88 18. 75	88 52. 50	89 26. 25

TABLE T.—*Conversion of degrees and minutes into mils*

Conversion factor—1 degree = 17.77778 mils;
1 minute = 0.29629 mil.

Degrees	Mils	Degrees	Mils	Degrees	Mils	Minutes	Mils	Minutes	Mils
1	17.8	31	551.1	61	1,084.4	1	0.3	31	9.2
2	35.6	32	568.9	62	1,102.2	2	0.6	32	9.5
3	53.3	33	586.7	63	1,120.0	3	0.9	33	9.8
4	71.1	34	604.4	64	1,137.8	4	1.2	34	10.1
5	88.9	35	622.2	65	1,155.6	5	1.5	35	10.4
6	106.7	36	640.0	66	1,173.3	6	1.8	36	10.7
7	124.4	37	657.8	67	1,191.1	7	2.1	37	11.0
8	142.2	38	675.6	68	1,208.9	8	2.4	38	11.3
9	160.0	39	693.3	69	1,226.7	9	2.7	39	11.6
10	177.8	40	711.1	70	1,244.4	10	3.0	40	11.9
11	195.6	41	728.9	71	1,262.2	11	3.3	41	12.1
12	213.3	42	746.7	72	1,280.0	12	3.6	42	12.4
13	231.1	43	764.4	73	1,297.8	13	3.9	43	12.7
14	248.9	44	782.2	74	1,315.6	14	4.1	44	13.0
15	266.7	45	800.0	75	1,333.3	15	4.4	45	13.3
16	284.4	46	817.8	76	1,351.1	16	4.7	46	13.6
17	302.2	47	835.6	77	1,368.9	17	5.0	47	13.9
18	320.0	48	853.3	78	1,386.7	18	5.3	48	14.2
19	337.8	49	871.1	79	1,404.4	19	5.6	49	14.5
20	355.6	50	888.9	80	1,422.2	20	5.9	50	14.8
21	373.3	51	906.7	81	1,440.0	21	6.2	51	15.1
22	391.1	52	924.4	82	1,457.8	22	6.5	52	15.4
23	408.9	53	942.2	83	1,475.6	23	6.8	53	15.7
24	426.7	54	960.0	84	1,493.3	24	7.1	54	16.0
25	444.4	55	977.8	85	1,511.1	25	7.4	55	16.3
26	462.2	56	995.6	86	1,528.9	26	7.7	56	16.6
27	480.0	57	1,013.3	87	1,546.7	27	8.0	57	16.9
28	497.8	58	1,031.1	88	1,564.4	28	8.3	58	17.2
29	515.6	59	1,048.9	89	1,582.2	29	8.6	59	17.5
30	533.3	60	1,066.7	90	1,600.0	30	8.9	60	17.8

NOTE.—This table may be used to convert degrees and hundredths to mils by changing position of decimal point; for example, to convert 78.25° to mils—

78.00° = 1386.7 mils
0.25° = 4.4 (44) mils

78.25° = 1391.1 mils

CHAPTER 9

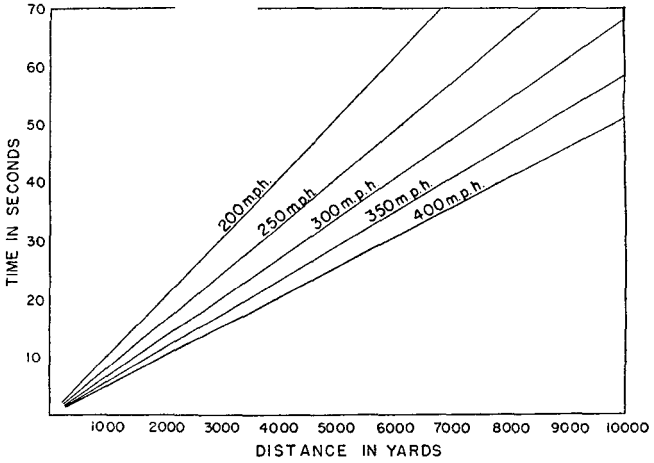
DATA IN REGARD TO AIRPLANES

TABLE U.—*Characteristics of airplanes* [a]

Type airplane	Maximum speed (miles per hour) [b]	Radius of action (miles) [c]	Service ceiling (feet)	Bombs (weight)	Guns, fixed	Guns, flexible [d]	Engines
Bombardment:							
Heavy	270	1,050	30,000	2 tons	None	2–8	2 or 4
Medium	310	500	26,000	1 ton	None	2–6	1 or 2
Light	285	250	30,000	½ ton	1–8	1–4	1 or 2
Dive	300	300	29,000	½ ton	1–2	2–6	1 or 2
Pursuit:							
Interceptor	375	175	35,000	None	4–8	None	1 or 2
Fighter	315	500	32,000	None	2–4	1–4	1 or 2
Reconnaissance	Same characteristics as heavy or medium bombardment.						
Observation:							
Airplane	150	250	28,000	None	1	1–2	1
Autogiro	125	50	14,000	None	None	None	1

[a] Data in this table is based on average characteristics of service airplanes.
[b] Cruising speed is 15 to 20 percent less than maximum speed.
[c] Radius of action equals 25 percent of specification range.
[d] Four gun turrets are installed on some airplanes.

TABLE V.—*Time-distance chart, airplanes*



Operation of chart

Known	Required	Operation
Distance and average speed.	Time necessary to complete movement.	From intersection of vertical line through distance scale and the proper speed line, read horizontally the time on the time scale.
Distance and time available.	Average speed necessary.	From intersection of vertical line through distance scale and horizontal line through time scale, read speed in miles per hour on speed line, interpolating if necessary.
Time available and average speed.	Distance covered.	From intersection of horizontal line through time scale and the proper speed line, read along vertical line the distance covered on the distance scale.

CHAPTER 10

DATA IN REGARD TO NAVAL VESSELS

TABLE W.—*Characteristics of warships* [a]

Type	Symbol	Displacement (tons)	Draught (mean) (feet)	Speed (designed) (knots)	Armament (guns)				Armor (inches)		
					Main battery		Secondary battery		Main belt	Turrets and barbettes or gun shields	Decks
					Number and caliber	Range (yards)	Number and caliber	Range (yards)			
Battleship	BB	26,000 to 40,000	25 to 36	22 to 30	8 to 12 11 inches to 16 inches.	24,000 to 35,000	8 to 20 5 inches to 6 inches.	17,000	5½ to 16	5 to 16	3 to 10½
Cruiser:											
Battle	CC	32,000 to 42,000	26 to 29	29 to 31	6 to 8 8 inches to 15 inches.	24,000 to 35,000	8 to 12 4 inches to 5.5 inches.	17,000	9 to 12	11 to 13	3 to 5½
Heavy	CA	7,100 to 10,000	15 to 20	32 to 36	6 to 10 8 inches.	18,000 to 35,000	4 to 12 3.9 inches to 5 inches.	15,000	0 to 5½	0 to 6	0 to 5

See footnotes at end of table.

TABLE W.—*Characteristics of warships*—Continued

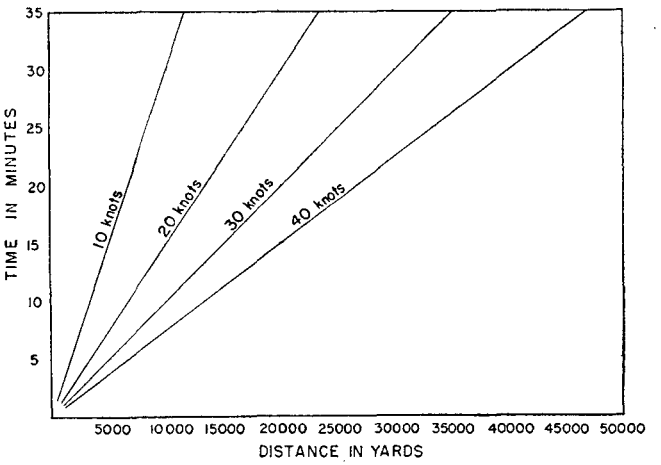
Type	Symbol	Displacement (tons)	Draught (mean) (feet)	Speed (designed) (knots)	Armament (guns)				Armor (inches)		
					Main battery		Secondary battery		Main belt	Turrets and barbettes or gun shields	Decks
					Number and caliber	Range (yards)	Number and caliber	Range (yards)			
Cruiser—Con.											
Light	CL	3,362 to 10,000	13 to 17	29 to 41	5 to 15—5.3 inches to 6.1 inches.	18,000 to 22,000	2 to 12—3 inches to 4 inches.[b]	15,000	0 to 4½	0 to 5½	0 to 3
Aircraft carrier	CV	7,100 to 33,000	15 to 25	22 to 34	8 to 16—4.5 inches to 8 inches.	15,000 to 20,000	Varying 5 inches or smaller.	15,000	0 to 6	Varying	1 to 5
Destroyer	DD	905 to 2,884	8 to 15	34 to 39	3 to 8—4 inches to 5.5 inches.[b]	15,000					
Submarine	SS	250 to 2,880[c]		13 to 20	1 to 4—1 inch to 8 inches.	7,000 to 15,000					

[a] Data included in this table are based on average characteristics of warships of great naval powers.

[b] Dual-purpose guns which may be used for firing at aerial, naval, or land targets.

[c] Surface.

TABLE X.—*Time-distance chart, naval vessels*



Operation of chart

Known	Required	Operation
Distance and average speed.	Time necessary to complete movement.	From intersection of vertical line through distance scale and the proper speed line, read horizontally the time on the time scale.
Distance and time available.	Average speed necessary.	From intersection of vertical line through distance scale and horizontal line through time scale, read speed in miles per hour on speed line, interpolating if necessary.
Time available and average speed.	Distance covered.	From intersection of horizontal line through time scale and the proper speed line, read along vertical line the distance covered on the distance scale.